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WASTEWATER MANAGEMENT ALTERNATIVES FOR THE CLEVELAND - AKRON, T--ETC(U)

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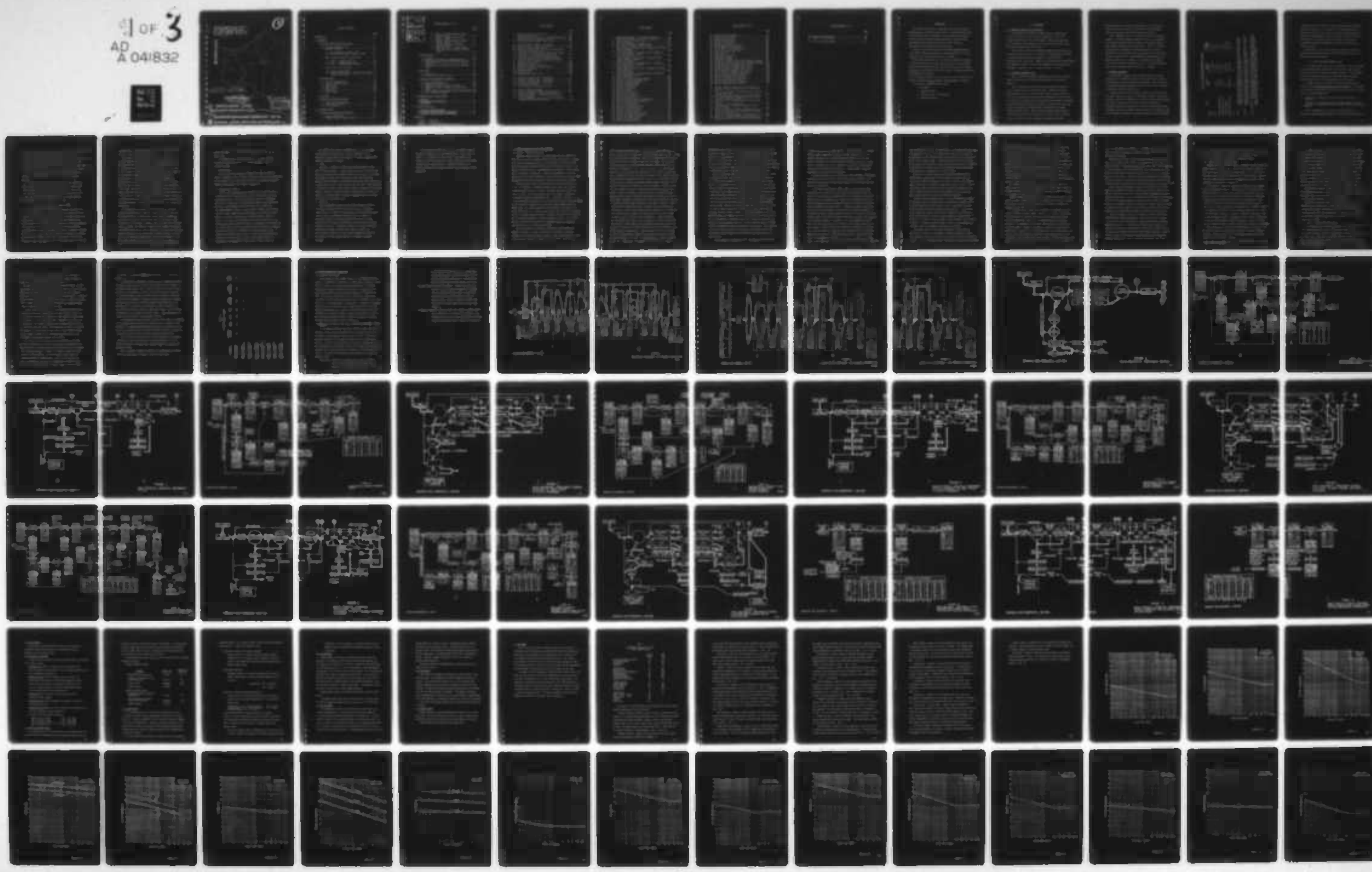

A Specialty Appendix on the De-ign and Cost of Wastewater Treatment Plants and Stormwater Treatment Facilities, pre-ered for the Buffalo District, U.S. Army Corps of Engineers, February, 1973

Buffalo

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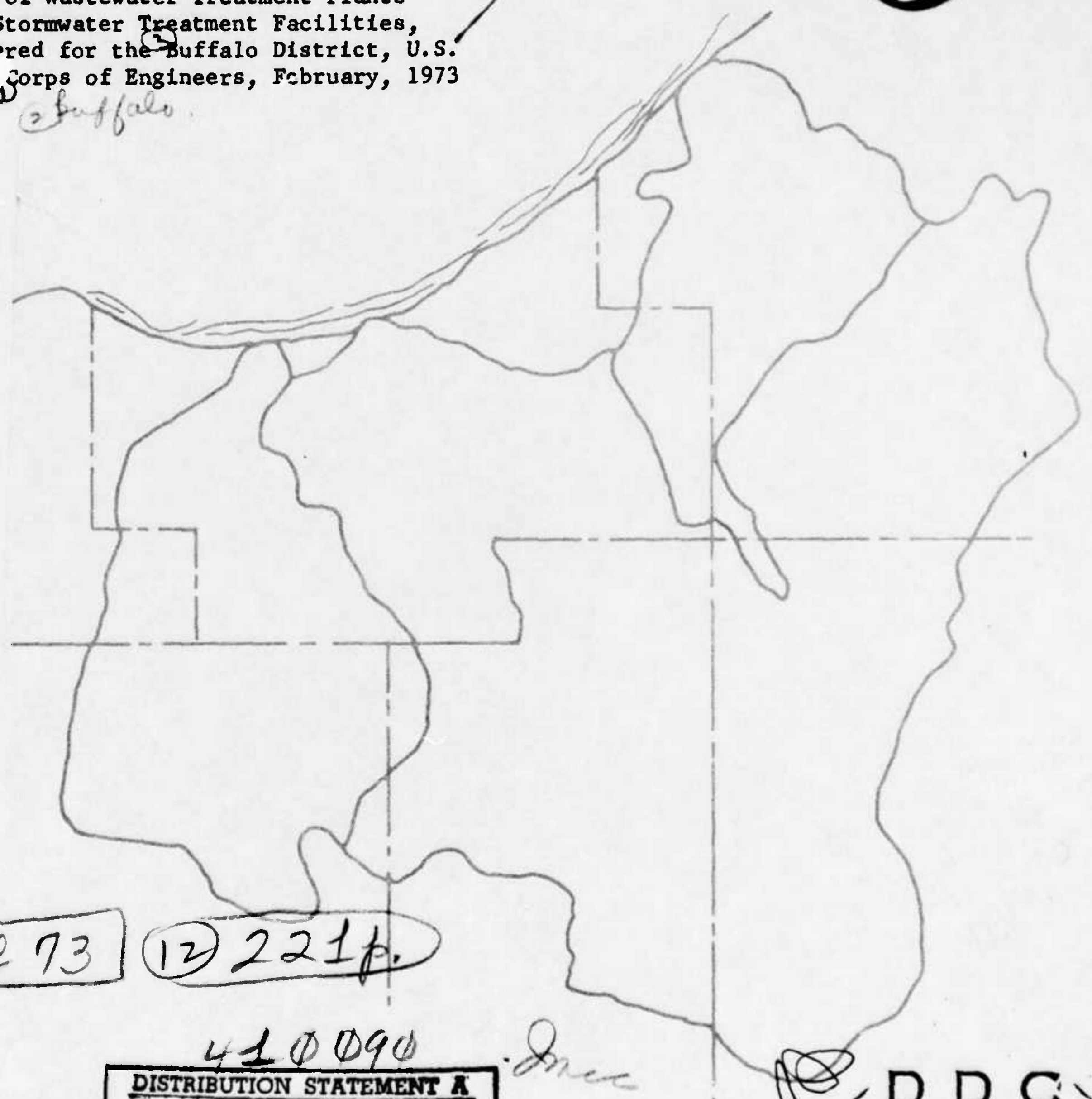

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TECHNICAL APPENDIX - PHASE II.

SYSTEM DESIGN AND ESTIMATE OF COST.

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WASTEWATER MANAGEMENT ALTERNATIVES FOR THE CLEVELAND - AKRON, THREE RIVERS WATERSHED AREA.

HAVENS AND EMERSON LTD. CONSULTING ENVIRONMENTAL ENGINEERS

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INTRODUCTION

This Survey Scope Study is a continuation of the preliminary work performed under the Feasibility Study in 1971. The Cleveland-Akron area was chosen by the Corps of Engineers as one of the five pilot areas in which to develop a wastewater management program. Three consulting engineering firms have been selected to work with the Corps in developing the Cleveland-Akron Survey Scope Study.

Phase I of the study identified the wastewater management problem with respect to domestic and storm water runoff wastewater as it exists today and as it is anticipated to exist in the future.

This report covers Phase II of the study which identifies treatment processes and effectiveness, design criteria, and unit costs associated with municipal wastewater treatment facilities and storm water treatment facilities. This report does not include, however, any data associated with land treatment of wastewater.

Also included in Phase II of the study were the cost estimates of the twelve alternative plans, as developed by Wright-McLaughlin, Engineers.

This report is presented in four sections:

A - Wastewater

B - Stormwater Runoff

C - Alternative Plans - Cost Estimates

D - Related Information

A - WASTEWATER

1. - TREATMENT PROCESSES AND EFFECTIVENESS

The development of a wastewater treatment plan for a municipality or political jurisdiction has two basic considerations. First, the required effluent quality must be established. Secondly, the applicable process sequence to most economically meet these requirements under local enviromental constraints must be selected.

In this section, three basic wastewater management treatment goals are established using State and O.C.E.* guidelines. Existing process technology is reviewed, and optimum process sequences, as most applicable in Northeastern Ohio, are selected. Schematic and illustrative flow-concentration-mass diagrams are used to characterize and compare unit process and system performance. Influent quality is prevented in Phase I - Section 6.

1.1 - WASTEWATER MANAGEMENT GOALS

Table 1 defines the wastewater management goals for Level 1 and Level 2. Detailed definitions of the required effluent quality are contained in Appendix C.

Level 1 represents the proposed effluent standards of the State of Ohio. The quality criteria contained in Level 1 represent the State's maximum quality criteria. The conventional indices of pollution, such as the 5-Day Biochemical Oxygen Demand (BOD_5) and Suspended Solids (SS), vary as a function of the receiving water classification and dilution availability. Allowable phosphorus discharges are defined as a function of the receiving water location and daily discharge volume of wastewater with maximum removals required by 1980. Ammonia nitrogen residuals vary seasonally as a function of the stream classification and available dilution. Effluent

*O.C.E. - Office of the Chief of Engineers, Department of the Army

dissolved oxygen (DO) concentrations are highest for receiving waters containing cold water fisheries. Allowable fecal coliform bacteria counts vary seasonally and dictate continuous disinfection.

Level 2 represents the O.C.E. Standards for municipal wastewater treatment. The major differences between State and O.C.E. standards are nitrogen removal, COD effluent standards, and increased removals of BOD_5, ammonia, phosphorus, and suspended solids. The O.C.E. effluent quality goals are independent of stream classification, dilution availability, receiving stream location, wastewater flows, and season of the year. Since the State's maximum effluent DO concentration is more stringent than the O.C.E. standard, it is assumed that an effluent DO of 6 mg/l or more must be achieved in Level 2. The State pH requirements were also assumed to apply for the O.C.E. standards.

1.2 TREATMENT TECHNOLOGY

All wastewater and waste solids treatment processes, excluding disinfection, are designed to promote a gaseous end product or separate and concentrate dissolved and particulate pollutants. The final gaseous or solid phase pollutant end product should be inert and of no pollutional significance in the final disposal site.

Treatment processes can be broadly classified as a function of the unit process goal. This concept is illustrated in Figures 1 (Wastewater Treatment: Unit Process Alternatives) and Figure 2 (Waste Solids Treatment: Unit Process Alternatives), where unit processes are defined in a generalized sequence of treatment steps such that a final product meeting any quality level can be achieved. These unit process flow diagrams should not be regarded as inflexible (often process goals can be and are combined

TABLE 1 - WASTEWATER MANAGEMENT STUDY GOALS

Item	Level 1	Level 2	Level 2 Modified
BOD_5	5 mg/1	$<$ 5.0 mg/1	$<$ 3.0 mg/1
COD		Use 10 mg/1	$<$ 5 mg/1
SS	8 mg/1	$<$ 5.0 mg/1	$<$ 1 mg/1
Total Phosphorus (As P)	0.5 mg/1	$<$ .5 mg/1	0.1-0.2
Ammonia Nitrogen (As N)	2.0 mg/1	$<$ 1.0 mg/1	0.3-0.5
Dissolved Oxygen	6.0	Use 6 mg/1	Use 6 mg/1
Fecal Coliform Bacteria	200/100 ml	200/100 ml	200/100 ml
pH	5-9	5-9	5-9

Level 1 - Extracted from a preliminary draft of proposed effluent standards for municipal, industrial and other wastewaters to the inland waters of Ohio (Water Pollution Control Board, Ohio Department of Health; June, 1972).

Level 2 - Extracted from proposed critical levels for wastewater constituents, letter from NCBED-PB, June 19, 1972 and meeting of July 17, 1972, Washington, D. C. Level 2 also refered to in this report as Federal or OCE Goals.

Level 2 Modified - From "Design Considerations for Advanced Waste Treatment Plants", August 31, Not used as information. Was not available at beginning of phase two work. Note: Inorganic constituents (heavy metals and dissolved solids) are excluded from municipal system design considerations. See report by AWARE.

in one physical unit) nor complete (rapidly expanding technology prevents totality) but rather as an illustration of the treatment alternatives available for application in a municipal wastewater management program. Definition of the management or water quality goals contained in Table 1 in conjunction with the elimination of economically unattractive or insufficiently demonstrated alternatives, reduces the multiplicity of treatment options.

For the purpose of this study, competitive process sequences incorporating basic biological and physical-chemical treatment processes for Northeastern Ohio were developed.

1.21 BASIC BIOLOGICAL TREATMENT SYSTEM

It is safe to conclude that, for the near future, the basic technology for municipal wastewater treatment will be a biological system combined with specific physical or chemical treatment techniques. This technology will most assuredly be applied to large existing wastewater treatment facilities and can be easily incorporated in new facility design.

In attempt to define the "typical" wastewater treatment facility for this area, The 1968 Municipal Waste Facility Inventory (U.S. Department of the Interior, Federal Water Quality Administration) reports the following for the Lake Erie Drainage Basin:

1. 98 percent of the population receives some form of wastewater treatment;
2. 79 percent of the population receives secondary treatment, of which, 93 percent is serviced by the activated sludge process or modifications thereof.

From the preceding, it can be seen that the foundation for an effective wastewater management program is already established: wastewater

collection and transport to a treatment site, and use of the activated sludge process as the representative treatment concept. Therefore, the activated sludge process with an aeration contact time of 4.5 to 6 hours is assumed as the one that must be upgraded to meet the various wastewater management goals listed in Table 1. The basic activated sludge system is shown schematically in Fig. 3, with anaerobic solids digestion followed by vacuum filtration and incineration. Typically, waste solids cake and incinerator ash are ultimately disposed of upon municipal landfill operations.

To provide a basis of comparison, the unit and overall equilibrium process performance of this system was prepared for the estimated 1990 influent wastewater quality as illustrated in Figure 3A. This system would only meet the proposed BOD_5 and SS criteria for Ohio's Class III streams (free flowing, warm water fisheries) if the average upstream BOD_5 concentration increase was no more than 1 mg/l.

1.22 BASIC PHYSICAL-CHEMICAL TREATMENT SYSTEM

Physical-chemical treatment systems, when applied, will most likely be at new treatment sites or as additions to existing primary facilities. In terms of volume, the largest of the new physical-chemical systems presently proposed will be at Cleveland's Westerly Wastewater Treatment Plant where a physical-chemical system incorporating single stage lime coagulation with lime recovery and reuse, recarbonation, filtration and granular activated carbon adsorption, regeneration and reuse is proposed. Alternative systems, such as at Rocky River, Ohio, replace lime addition with polymer applications for suspended solids removal and add metal salts to meet phosphorus removal requirements. The Cleveland Westerly plant was assumed

the representative physical-chemical system for this study and its flow pattern is shown schematically in Figure 4.

Equilibrium system performance is illustrated in Figure 4A for the 1990 influent wastewater quality. The system, as proposed, is designed to maximize the phosphorus removal to lime dosage ratio with an influent wastewater alkalinity of 175 mg/l as $CaCO_3$. At a lime dose of about 240 mg/l as $Ca(OH)_2$, a reaction pH of about 10.5 should result. At this pH minimal $Mg(OH)_2$ precipitation will result and calcium solubilization will be minimal (thus, maximizing $CaCO_3$ formation). Recarbonation is provided to adjust the wastewater pH prior to carbon adsorption and to solubilize any effluent $CaCO_3$ to prevent encrustation of the filter. The filtration system is provided to protect the activated carbon system from particulate solids. The granular activated carbon system is shown with air or oxygen applications to prevent problems with septicity and effluent clarity and to meet effluent dissolved oxygen concentrations. A 30 percent wastage of calcined ash was assumed in the lime recovery and reuse system.

The proposed physical-chemical system, as shown, can meet Ohio's proposed minimum BOD_5 and SS effluent standards for Class I (cold water fisheries) and Class II (scenic waters) streams when the average BOD_5 concentration increase at critical stream flows is less than 0.3 mg/l and some Class III and Class IV (pooling waters with warm water fisheries) receiving streams. Ohio ammonia nitrogen effluent standards for November through March with Class III and IV streams are satisfied if the calculated ammonia concentration in the stream does not exceed 0.05 mg/l. The 1980 Ohio effluent phosphorus standards are satisfied for discharges of less than 10 mgd into Lake Erie and its tributaries. If the discharge is into a lake, reservoir, impoundment or pool, the system meets the proposed

phosphorus standard only when discharged volumes of wastewater are less than 1 mgd.

In comparing Figures 3A and 4A, fundamental differences between biological and physical-chemical systems become apparent. These are briefly reviewed.

a. Waste Solids

Waste sludge solids are generally higher for a physical-chemical system. Oftentimes, this is partially compensated for by improved dewaterability. The utilization of lime rather than a metal salt as the primary coagulant causes this difference to be especially pronounced.

b. Soluble Organic Removal

Economic and performance success or failure of this process goal in a biological system is dependent upon the main stream reactor and solids separation; whereas with a physical-chemical system it is dependent upon the main stream reactor and sidestream activated carbon regeneration and reuse. The biological system cannot remove highly refractory (non-biodegradeable) organics, but when effluent standards are developed in terms of BOD_5, nondescriminate bio-degradeable and refractory organic removal by activated carbon make very low BOD_5 residuals difficult to achieve. A biological system metabollically converts about 1/4 to 1/2 of the applied organic carbon to CO_2 which is discharged to the atmosphere; in a strict sense, the physical-chemical system must handle this additional organic carbon which is not removed until carbon regeneration upon application of external energy or fuel. Although biological system can be upset by inhibitory wastes, activated carbon organic adsorption performance is pH dependent for organic acids and bases, anionic and

cationic surface active agents, and ampholytes; their removal cannot be simultaneously optimized for in a municipal wastewater since adjustment of pH may increase the removal of one organic compound while suppressing adsorption of others.

c. Costs

Generally, a trade-off is made when selecting biological versus physical-chemical systems. A physical-chemical system will usually show lower capital costs with its shorter reactor times. However, its operating expenditures and energy costs are generally higher than biological systems because of chemical costs and side-stream regeneration requirements. In urban areas with very little available land, the smaller land requirement of the physical-chemical system imparts an obvious advantage over biological systems. Generally, the physical-chemical components have a shorter life because of the larger amount of mechanical equipment which in turn tends to increase the total annual cost.

d. Unknowns

The disadvantages of the more conventional biological systems are well known and understood because of 40 or more years of experience. However, there are a number of unknowns about a physical-chemical process which may reduce its superficial attractiveness. For example, a lime-carbon system on raw wastewater application has not yet been supported by the successful demonstration of lime and activated carbon regeneration and reuse. Temperature influences upon carbon adsorption effectiveness represent an almost total unknown as well as the necessary reserve capacity to satisfy largely unbuffered diurnal flow and organic variations normally exhibited in municipal wastewater treatment.

In the following sections, these two basic wastewater treatment concepts are upgraded to meet the effluent quality levels listed in Table 1. It is thought that these process schemes represent an optimum and realistic application of today's technology to meet future treatment goals. Where applicable, fundamental comparisons of design alternatives are discussed and major risks and unknowns briefly enumerated.

1.3 - PROCESS SEQUENCE SELECTION AND PERFORMANCE

1.31 - LEVEL 1: PROPOSED STATE GOAL

BIOLOGICAL TREATMENT SYSTEM: The proposed Ohio effluent standards or state goal can be met by achieving ammonia oxidation (nitrification), applying metal salts for phosphorus removal, controlling effluent solids by organic polymer addition and in-depth filtration, and practicing post aeration. The upgraded biological system is shown schematically in Figure 5. System performance is illustrated in Figure 5A. As shown on these figures, the solids handling system has also been modified to include gravity waste activated sludge thickening and heat conditioning of the combined raw sludge after storage.

To achieve nitrification, the existing aerator has been separated into a 1/3 - 2/3 (high rate - nitrifying) volumetric split which would result in a nitrifying contact time of 3 to 4 hours, assuming the original aerator contact time was 6 hours. This new nitrifying contact time should be adequate for the climatic conditions of Northeastern Ohio. A new final clarifier is necessary to allow the complete separation of the two distinct biological cultures, designed for the removal of carbonaceous and nitrogenous oxygen demanding materials respectively. This system alternative for nitrification was selected over other possibilities (i.e., chemical additions and solids control in the primary clarifier, extended aeration) because in a general application this alternative gives the greatest assurance of economic performance success. It is also most compatible with metal salt addition for phosphorus removal and maximizes the potential for a low soluble BOD_5 residual.

Metal salt addition for phosphorus removal was selected because the chemical requirement is largely a function of the pollutant of concern, phosphorus, and the required soluble residual. Thus, should phosphorus levels in the influent wastewater be reduced by local or federal legislation or

should detergent reformulations occur in the future, the municipality will be able to reduce metal salt applications and derive proportional savings. As shown, metal salt additions for phosphorus removal do not require additional capital facilities other than a chemical storage and feed complex. Any source of precipitating metal ion, including some industrial wastes, can be used, but because of the generality of this study the alternatives have been reduced to commercially available ferric and aluminum salts, i.e., ferric chloride and alum. Aluminum was selected over ferric iron because of its higher pH value of optimum phosphorus precipitation (about 6 versus 5), its lower mass of precipitated solids, its precipitate's integrity during reducing conditions, and the absence of potential color problems in the final effluent. Although the metal salt can be added to any point in the major process stream, dosing to the aerator effluent was selected to maximize hydrolysis of influent complex phosphorus forms, minimize competing soluble phase side reactions due to raw waste organic components, and minimize floc shearing and upwards pH drift due to shearing and carbon dioxide stripping in the aerator. Dosing the chemical to the activated sludge system does not attenuate process performance but, rather provides a stabilizing influence upon the system due to the weighting effect derived from the inorganic precipitate within the activated sludge floc which results in a denser, faster settling floc. Chemical additions into the secondary also results in the accumulation of chemical precipitate which provides a buffer against diurnal phosphorus concentration peaks and lessens the sensitivity of chemical application rates to fluctuations in raw sewage phosphorus concentrations. A polishing dose of metal salt is added to the nitrifying activated sludge system to produce the required effluent phosphorus residual of 0.5 mg/l. By incorporating split-chemical treatment, only a small additional dose of aluminum is required, and the resultant

precipitated solids would not be expected to upset the system. The liability of metal salt addition for phosphorus removal is the introduction of extraneous ions which, in some instances, can be considered contaminants in their own right. In the case of alum, approximately 5.3 parts of sulfate are introduced per part of aluminum added. Although sulfate levels will increase over background levels, a net dissolved solids increase does not result due to the almost completely compensating removal of phosphate and other soluble phase pollutants.

Polymer addition and some physical means of final effluent solids control are design necessities when low phosphorus residuals are required whether or not low BOD_5 and SS residuals are treatment necessities. Polymer addition usually is a treatment necessity because of the colloidal haze that can occur with high dosages of precipitating chemicals. Anionic polyelectrolyte addition in conjunction with aluminum additions has resulted in excellent process stream clarity after simple sedimentation. The filtration system provides positive backup for the system and further effluent polishing. A dual or multi-media filtration system has been selected because of the low effluent suspended solids required. Examining the process streams before (E-2) and after filtration (FE) in Figure 5A shows that although the State BOD_5 and SS effluent standards can be met before filtration, precipitated phosphorus in the solids phase dominates, and effluent solids control by filtration should be provided. In the final effluent, differences between total nitrogen (N_t) and oxidized nitrogen (N-O) will largely consist of a soluble refractory organic nitrogen residual with ammonia nitrogen concentrations at trace levels. Lime additions in the nitrification system for this wastewater were necessary because of anticipated alkalinity depletions associated with metal salt addition and nitrification.

Chlorine dosages for disinfection would be reduced due to the absence

of ammonia nitrogen in the final effluent. No credit was taken for BOD_5 and ammonia removal through the disinfection system. Chlorination for final effluent disinfection is an acceptable practice under current State and Federal regulations, even though chlorinated effluents can possess a certain toxicity to aquatic life. If not acceptable in the future, dechlorination can be practiced by chemical additions, i.e., sodium bisulfite, sulfite, thiosulfate or activated carbon adsorption.

To produce consistently an effluent with a dissolved oxygen concentration of 6 mg/l or more in the summer, a post-aeration step is necessary. The post-aeration step could be added before, during, or after conventional chlorination for disinfection.

In the waste solids handling system, gravity waste activated sludge thickening was provided over such alternatives as dissolved air flotation because it was felt that the weighting action of the inorganic precipitates should serve as a concentrating aid. Waste activated sludge return to the primary sedimentation tank was eliminated because of inevitable problems with solids resuspension and poorer capture. Although no problems would be expected with the anaerobic digestion system due to the inorganic precipitates, the additional mass of waste biological solids due to the high rate activated sludge system, and improved main stream solids capture may impair the operation of the anaerobic digester. In addition, it is not unreasonable to expect that the vacuum filter cake for this condition would slightly increase in its water content. Therefore, the primary digester was converted to a storage tank, heat conditioning of sludge solids was incorporated, and the secondary digester was converted to a decanting-storage facility. Heat conditioning offers the advantages of consistency in vacuum filter operation, increased cake dryness, high cake BTU values, and a "sterile" end product should conditioned

sludge application to the land be contemplated. Its disadvantages center upon the magnitude of volatile solids solubilization which, if not completely biodegradeable, can deteriorate effluent organic values and will increase the mass of waste activated sludge. Nitrogen solubilization will be similar to that encountered with anaerobic digestion achieving 50 percent solids destruction. If considered in the basic design, the disadvantages associated with heat conditioning can be compensated for in system sizing.

Whether or not gravity waste activated sludge thickening and heat conditioning are incorporated, the final effluent from this plant will easily meet or exceed the proposed Ohio effluent standards. The aluminum-organic sludge may be incinerated or spread directly on the land. With land applications, the soil building and fertilizing benefits derived from the solid's organic fraction will more than compensate for any deleterious effect associated with the inorganic aluminum precipitates.

PHYSICAL-CHEMICAL TREATMENT SYSTEM: To meet the proposed Ohio effluent standards, the basic physical-chemical system must be upgraded to provide additional phosphorus and BOD_5 removal as well as incorporate a physical system specifically intended for ammonia nitrogen removal. To this end, a second stage flocculator-clarifier has been incorporated with breakpoint chlorination followed by additional carbon adsorption. Additional post aeration is a necessity to meet an effluent dissolved oxygen value of 6 mg/l or greater. The upgraded physical-chemical system is shown schematically in Figure 6 with its performance characterized in Figure 6A.

The reaction pH in the first stage flocculator-clarifier must be increased to 11.5 from 10.5 to achieve the additional phosphorus removal. This requires the lime dose to increase by almost 80 percent and necessitates the addition of a second-stage flocculator-clarifier to capture the precipitated

calcium carbonate following recarbonation to a pH 9.5. This results in an almost 50 percent increase in waste solids mass due to the additional calcium carbonate and precipitated magnesium hydroxide. A polishing dose of metal salts for phosphorus removal was not possible because of a lack of pH compatibility in the main and/or waste solids streams. The performance and chemical requirements for phosphorus removal with this system are largely independent of incoming phosphorus concentrations but vary as a function of pH dependent solubility products and the wastewater alkalinity. Thus, the system is insensitive to diurnal variations in phosphorus concentration but cannot be expected to return any economic savings should raw sewage phosphorus levels be reduced in the future.

In a physical-chemical system ammonia nitrogen removal cannot be by simple conversion to nitrate nitrogen but must be an actual physical removal. Commonly visualized techniques with today's technology are ammonia stripping, ion exchange, and breakpoint chlorination.

Ammonia stripping is compatible with lime treatment at pH values of 11 or greater but even if ammonia fluxing to the atmosphere were allowed, it suffers from physical scaling problems and performance limitations at ambient air temperatures less than 40° to 45°F.

Ion exchange using clinoptilolite, a naturally occurring zeolite, can produce an ammonia nitrogen residual of about 0.5 to 1.0 mg/l but questions with resin attrition, recovery and reuse as well as ultimate ammonia concentrate disposal still remain. If it is assumed that ultimate ammonia disposal to the atmosphere is not allowed, four alternatives for disposal of waste brine remain: breakpoint chlorination, biological nitrification and denitrification, disposal of a weak NH_4OH solution to an available market, and evaporation to a point where the dried salts can be handled directly in an incinerator. Since alternatives one and two offer no particular advantages over main stream contacting, and alternative three has no application in a generalized

study, only alternaitve four remains. It is thought, that the cost of drying this brine would be economically prohibitive in comparison to main stream breakpoint chlorination.

Breakpoint chlorination, following carbon adsorption for organic nitrogen removal, will produce a total effluent nitrogen of about 2 mg/l (about 1 mg/l organic nitrogen, 0.5 mg/l ammonia trichloride, and 0.5 mg/l oxidized nitrogen) with direct ammonia removal to nitrogen gas. This system suffers from the liability of dissolved solids addition and generally necessitates chemical additions for pH control. Clearly, for physical-chemical systems (including such exotic processes as distillation) the nitrogen removal question through ultimate disposal may determine their general applicability in wastewater treatment.

Ammonia removal by breakpoint chlorination is proposed as the means of meeting the proposed Ohio effluent standards for a physical-chemical system since at this point in time it has the least amount of unknowns and potential operating difficulties. It has the advantage that operating costs are directly a function of the applied ammonia mass and the required effluent residual. Should it be infeasible to handle the magnitude of chlorine indicated, either by purchase or on-site generation, the alternative technique would be ion exchange with ultimate ammonia disposal by evaporation and incineration.

As noted in Figures 6 and 6A, the breakpoint chlorination system is incorporating an expanded disinfection tank following the first stages of carbon contacting to remove organic nitrogen and competitive chlorine demanding materials. It is followed by a downflow carbon contactor for additional solids removal, dechlorination, and additional organic removal (included any chlorinated hydrocarbons formed during breakpoint chlorination). No actual organic (COD) removal was taken during the actual breakpoint operation because of the very slow reaction rates without such catalysts as

ultra-violet radiation. Obviously, effective disinfection and virus kill will occur during breakpoint chlorination. Post aeration should be provided either before or after the final stage of carbon contacting.

1.32 - LEVEL 2: PROPOSED TREATMENT GOAL

ADVANCED BIOLOGICAL TREATMENT SYSTEM: Biological nitrogen and refractory organic removal must be provided to meet the O.C.E. effluent standards. In terms of new capital facilities, as shown in Figure 7*, the system used to meet Level 2 must be a denitrification reactor, aerated channel, final clarifier and a carbon adsorption system with regeneration and reuse. Process performance is illustrated in Figure 7A*.

The alternative systems for biological denitrification are suspended versus attached growth reactors. Denitirfication, like nitrification, is a temperature sensitive reaction where contacting times per unit mass of biological flora and cell residence times are both temperature dependent. A suspended growth reactor was selected over an attached growth system (coarse filter) because of its greater operating flexibility under the temperature variations encountered in Northeastern Ohio. Methanol is added to the system to serve as the driving carbonaceous substrate and to accelerate the biological reduction of nitrate to elemental nitrogen gas. The magnitude of methanol addition is dependent upon the oxidized nitrogen mass into the unit and the required treatment efficiencies; effluent oxidized nitrogen values of 1.0 mg/l are easily obtained with no methanol breakthrough.

The polishing metal salt dose has been transferred to the end of the denitrification reactor and increased to achieve the required phosphorus residual. Ash shown in Figure 7A*, low phosphorus residuals are easily achieved with split chemical treatment.

*Federal Effluent Standards refer to standards established by O.C.E. (Office of the Chief of Engineers).

The required effluent COD is only achieved with additional treatment for refractory organic removal even though BOD_5 and suspended solids goals are satisfied after denitrification and filtration. The activated carbon requirement for this application is only about 1/10 to 1/5 of that associated with the physical-chemical system upgraded to satisfy the proposed state effluent standards (Figure 6A). Similar savings are derived in the spent carbon dewatering and regeneration system and makeup carbon storage. To produce an effluent free of chlorine toxicity, the disinfection facility could be located prior to carbon adsorption. However, since the chlorine dose for disinfection would undoubtedly be low, the disinfection facility has been left as the final treatment process in the treatment scheme.

ADVANCED PHYSICAL-CHEMICAL TREATMENT SYSTEM: Figure 8* shows schematically the upgraded physical-chemical system to satisfy the proposed O.C.E. effluent standards. The system's performance is illustra ed in Figure 8A*. Ozonation is incorporated as the means of further effluent polishing.

Ozonation was necessary because it is doubtful if a physical-chemical treatment system incorporating activated carbon adsorption can achieve the required soluble organic concentrations due to the previously mentioned pH influences upon adsorption effectiveness. Ozonation will simultaneously provide further disinfection and achieve the required effluent dissolved oxygen concentrations.

1.33 - LEVEL 3: MAXIMUM REUSE APPLICATION

In the water rich area of Northeastern Ohio, the probability of waste-water renovation for direct potable reuse is very remote. However, the two basic treatment systems have been carried to this point to illustrate the technological requirements and probabl process performance. Further-more, although total stream treatment is shown, it is projected that in

*Federal Effluent Standards refer to standards established by O.C.E. (Office of the Chief of Engineers).

the future, fractions of the major process stream would be diverted to constant flow minor process sequences specifically designed to produce a product water to match the intended reuse application.

ADVANCED BIOLOGICAL AND PHYSICAL-CHEMICAL TREATMENT SYSTEMS: To meet the ultimate product water goal of direct potable reuse, both basic treatment systems must be upgraded for demineralization and "fail-safe" treatment redundancy. The unit process selected for this is reverse osmosis. Schematic flow and process performance diagrams for the upgraded biological system are shown in Figures 9 and 9A with similar diagrams for the upgraded physical-chemical system contained in Figures 10 and 10A.

Reverse osmosis was chosen over the other available demineralization processes (distillation, electrodialysis, and ion exchange) because it is the one process technique which potentially could replace all the preceding unit processes. In other words, it offers a capability of backing up and supporting the total treatment system giving 100 percent pollutant removal redundancy with the added benefit of demineralization. Such a unit process is necessary in a closed recycle system because of the potential buildup of trace organic carbonaceous and nitrogenous pollutants which may be unremovable in the upstream treatment unit processes.

It is likely that the buildup of these trace pollutants and their successful elimination will be more of an operational consideration than demineralization in a closed system and, thus, demand total flow treatment rather than split treatment to achieve some higher, tolerable dissolved solids in the final effluent. No other treatment concept offers the treatment potential of reverse osmosis. Unfortunately, the state of today's technology will not allow it to supersede the upstream systems due to flux and membrane fouling limitations. These problems are likely

to be solved in the future; leaving only the question of what to do with the waste brine.

In Northeast Ohio, assuming that brine disposal to underground cavities or surface waters is invalid, there is little choice but to go through an evaporation system where it must be dried to a point that it can be handled directly in an incinerator. The water in this brine cannot be recovered by direct distillation since as the waste volume is reduced the potential of distillate contamination by organics and residual ammonia will increase. Multiple redistillation or distillate treatment (carbon adsorption, ion exchange, etc.) are possible but would mean that higher purity water is only achieved with smaller recovered produce water volumes. This illustrates a fundamental fact of wastewater treatment, namely: zero contaminants in a product water are found only with zero product water.

In the upgraded biological system, the dried mineral salts can be handled in an expanded incineration system in conjunction with the organic solids. Whereas, in the upgraded physical-chemical system which incorporates solids reuse, the evaporated mineral salts must be handled separately in an unique incineration system to avoid fractional solubilization upon reuse.

Both systems are followed by final chlorine disinfection for consumer protection in the event of distribution system contamination. An off-stream storage tank is provided should consumer demands not coincide with wastewater flows.

Table 2 presents a comparative summary of the effluent quality achieved from the various levels of treatment as previously described.

TABLE 2

EFFLUENT QUALITY (mg/1)

Treatment	Suspended Solids	BOD_5	COD	TOD	Total Nitrogen	Total Phosphorus	Figure No.
Basic Biological Treatment Plant	25	15	69	113	19.7	10.2	3A
Basic Physical-Chemical Treatment	5	15	45	89	13.1	0.7	4A
Level 1, Biological Treatment Plant	2	4	26	10	17.2	0.5	5A
Level 1, Physical-Chemical Treatment	2	5	15	14	2.0	0.2	6A
Level 2, Biological Treatment Plant	0	0	8	1	0.7	0.1	7A
Level 2, Physical-Chemical Treatment	1	0	8	7	2.0	0.2	8A
Level 3, Biological Treatment Plant	0	0	1	0	<0.1	0	9A
Level 3, Physical-Chemical Treatment	0	0	1	1	0.2	0	10A

1.4 MISCELLANEOUS DESIGN ASSUMPTIONS

1.41 HYDRAULIC SURGE CONTROL

In the design of these systems, the necessity of dampening hydraulic surges in the treatment systems has not been mentioned. Generally, for plant flows of 10 mgd or less, hydraulic surge control would be a worthwhile consideration because of wide diurnal variations. At higher daily flow rates hydraulic peaks are usually dampened because of the large service area. The necessity of providing positive influent flow control would be subject to the particular flow patterns found or anticipated at the treatment site. If flow equalization or surge control is necessary, an expanded sedimentation tank receiving the mixed liquor solids from the activated sludge system designed for the removal of carbonaceous materials would be recommended for the basic biological treatment system whereas with the basic physical-chemical treatment system a separate flow equalization chamber following chemical treatment would be recommended.

1.42 REMOVAL OF HEAVY METALS, PESTICIDES, CHLORINATED HYDROCARBONS, RADIOACTIVE MATERIALS

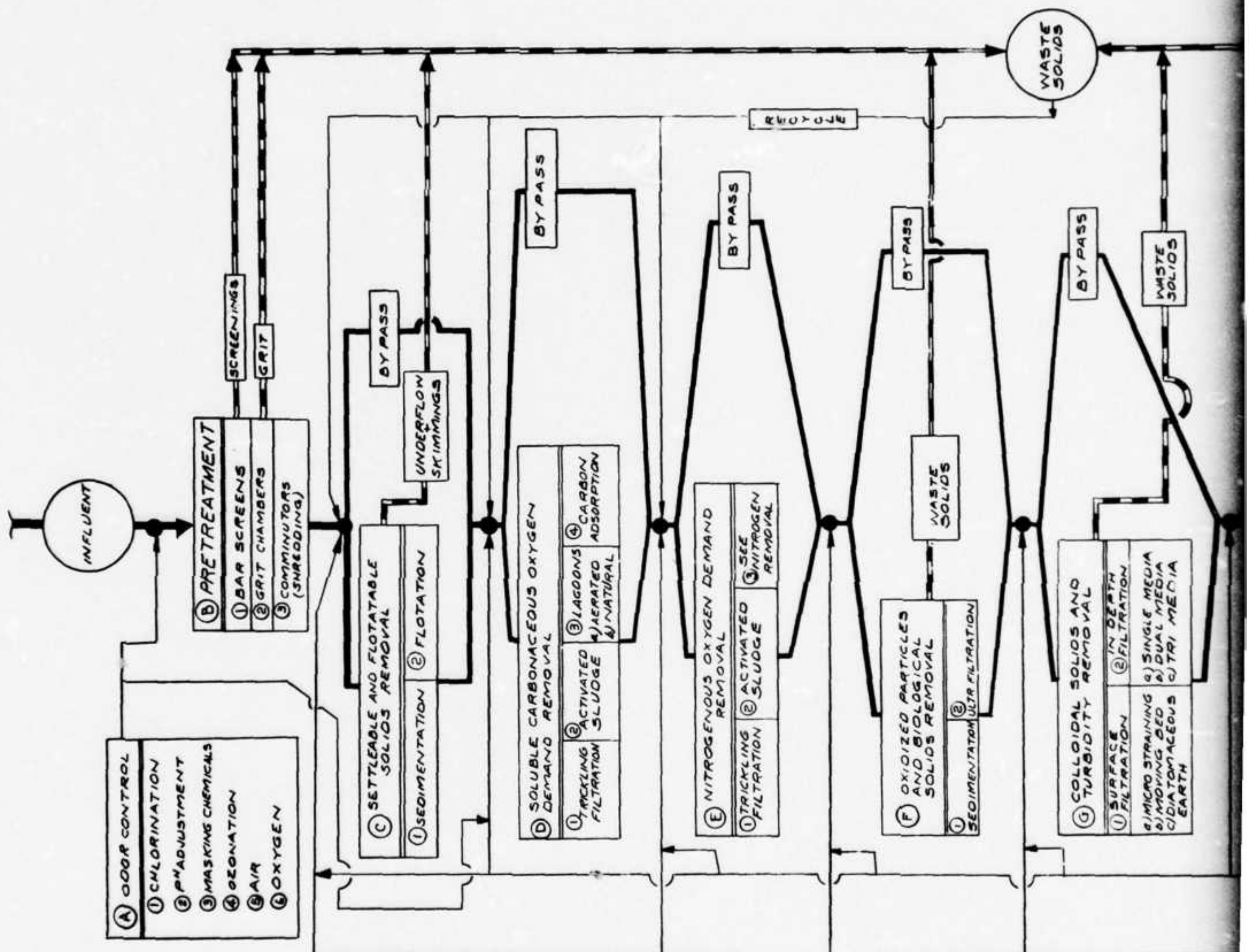
In the design of municipal wastewater treatment systems, specific process designs to remove the above pollutants were not considered since control at the source has been postulated in these studies. However, many of the unit processes contained in the treatment sequence can and do provide positive removals. Generally, with the exception of aeration stripping, the processes will concentrate these pollutants in waste solid streams which with and without incineration will reduce the feasible alternative for ultimate waste solids removal. As a review, the pollutants and unit processes for removal are summarized below:

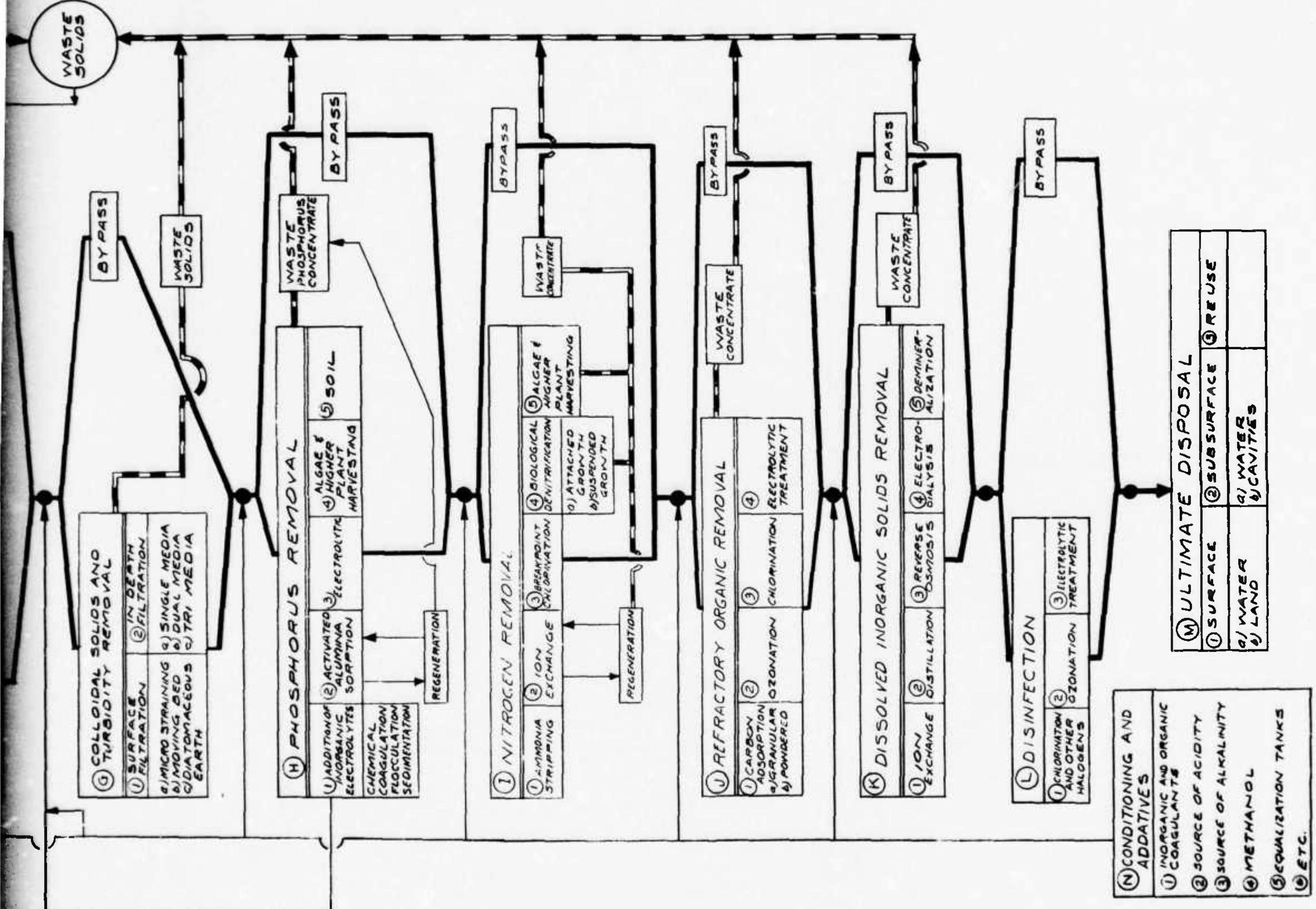
Heavy metals - "sorbed" onto biological floc, some precipitated with alum and trace quantities of sulfide, organic compounds adsorbed upon activated carbon, excellent

removal generally found with high pH lime treatment reverse osmosis should provide good removal. With or without incineration, possibility of resolubilization under microbial action in final disposal site exists.

Pesticides and Chlorinated Hydrocarbons - "sorbed" onto biological floc and can be fractionally stripped into atmosphere via the biological aeration systems. Adsorbed upon activated carbon with backup support provided by reverse osmosis. Permanent oxidation provided under incineration or carbon regeneration at elevated temperatures.

Radioactive Materials - See heavy metals for removals, complete capture may be impossible. Final destruction technique is time dependent upon given half-lifes. Distribution in gaseous, liquid and solid phases after treatment can be expected.


INFLUENT
B PRETREATMENT
1 BAR SCREENS
2 GRIT CHAMBERS
3 COMMINUTORS (SHREDDING)
SCREENINGS
GRIT
A ODOR CONTROL
1 CHLORINATION
2 pH ADJUSTMENT
3 MASKING CHEMICALS
4 OZONATION
5 AIR
6 OXYGEN
C SETTLEABLE AND FLOTATABLE SOLIDS REMOVAL
1 SEDIMENTATION
2 FLOTATION
BY PASS
UNDERFLOW SKIMMINGS
D SOLUBLE CARBONACEOUS OXYGEN DEMAND REMOVAL
1 TRICKLING FILTRATION
2 ACTIVATED SLUDGE
3 LAGOONS a) AERATED b) NATURAL
4 CARBON ADSORPTION
BY PASS
E NITROGENOUS OXYGEN DEMAND REMOVAL
1 TRICKLING FILTRATION
2 ACTIVATED SLUDGE
3 SEE NITROGEN REMOVAL
BY PASS
F OXIDIZED PARTICLES AND BIOLOGICAL SOLIDS REMOVAL
1 SEDIMENTATION
2 ULTR FILTRATION
WASTE SOLIDS
BY PASS
RECYCLE
WASTE SOLIDS
G COLLOIDAL SOLIDS AND TURBIDITY REMOVAL
1 SURFACE FILTRATION
a) MICRO STRAINING
b) MOVING BED
c) DIATOMACEOUS EARTH
2 IN DEPTH FILTRATION
a) SINGLE MEDIA
b) DUAL MEDIA
c) TRI MEDIA
BY PASS
WASTE SOLIDS

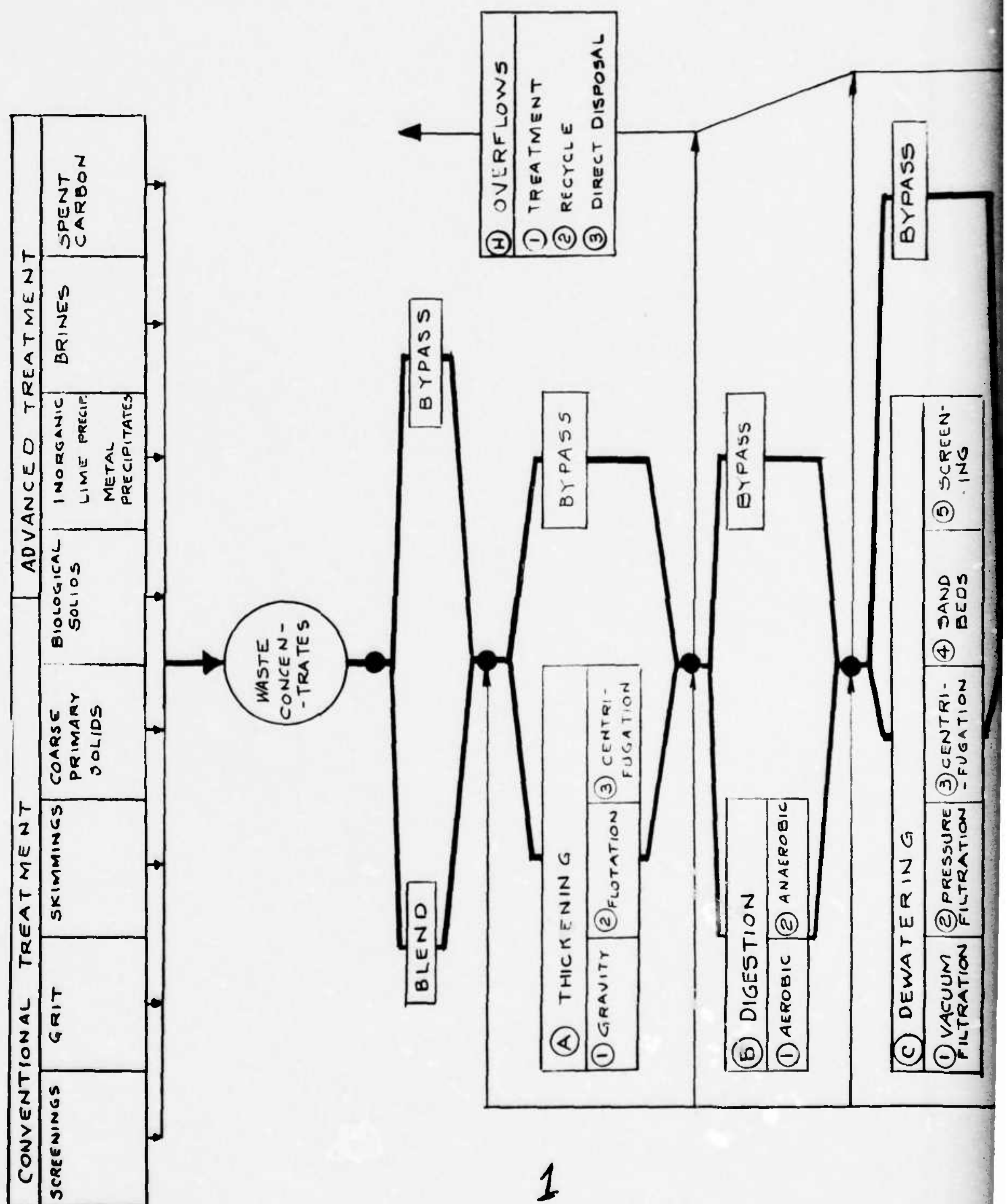


2

FIGURE-1

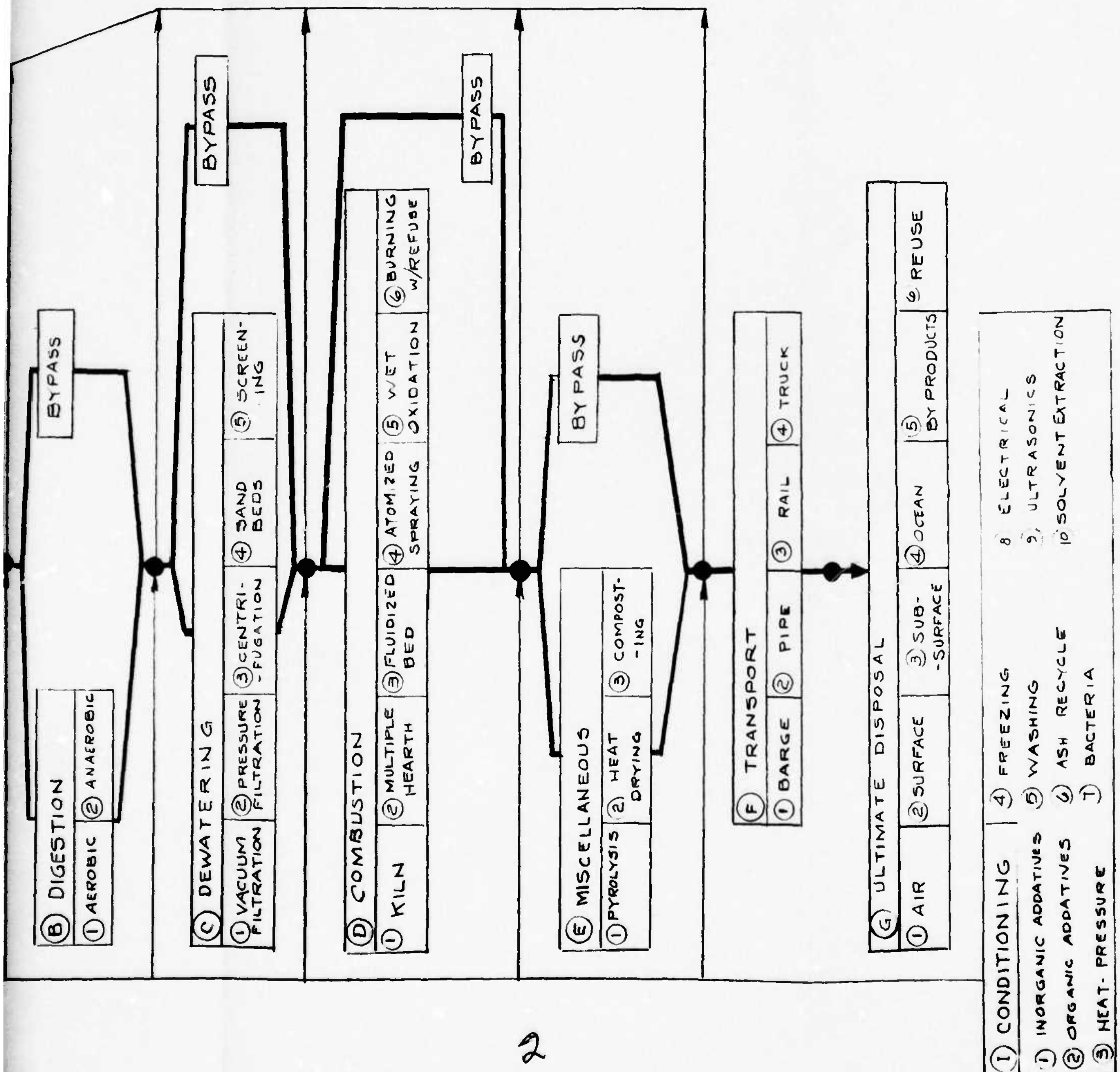
WASTEWATER TREATMENT: UNIT PROCESS ALTERNATIVES

FIGURE 2 - WASTE SOLIDS TREATMENT



1

SOLIDS TREATMENT: UNIT PROCESS ALTERNATIVES



2

FIGURE 2

WASTE SOLIDS TREATMENT: UNIT PROCESS ALTERNATIVES

SOLIDS TREATMENT: UNIT PROCESS ALTERNATIVES

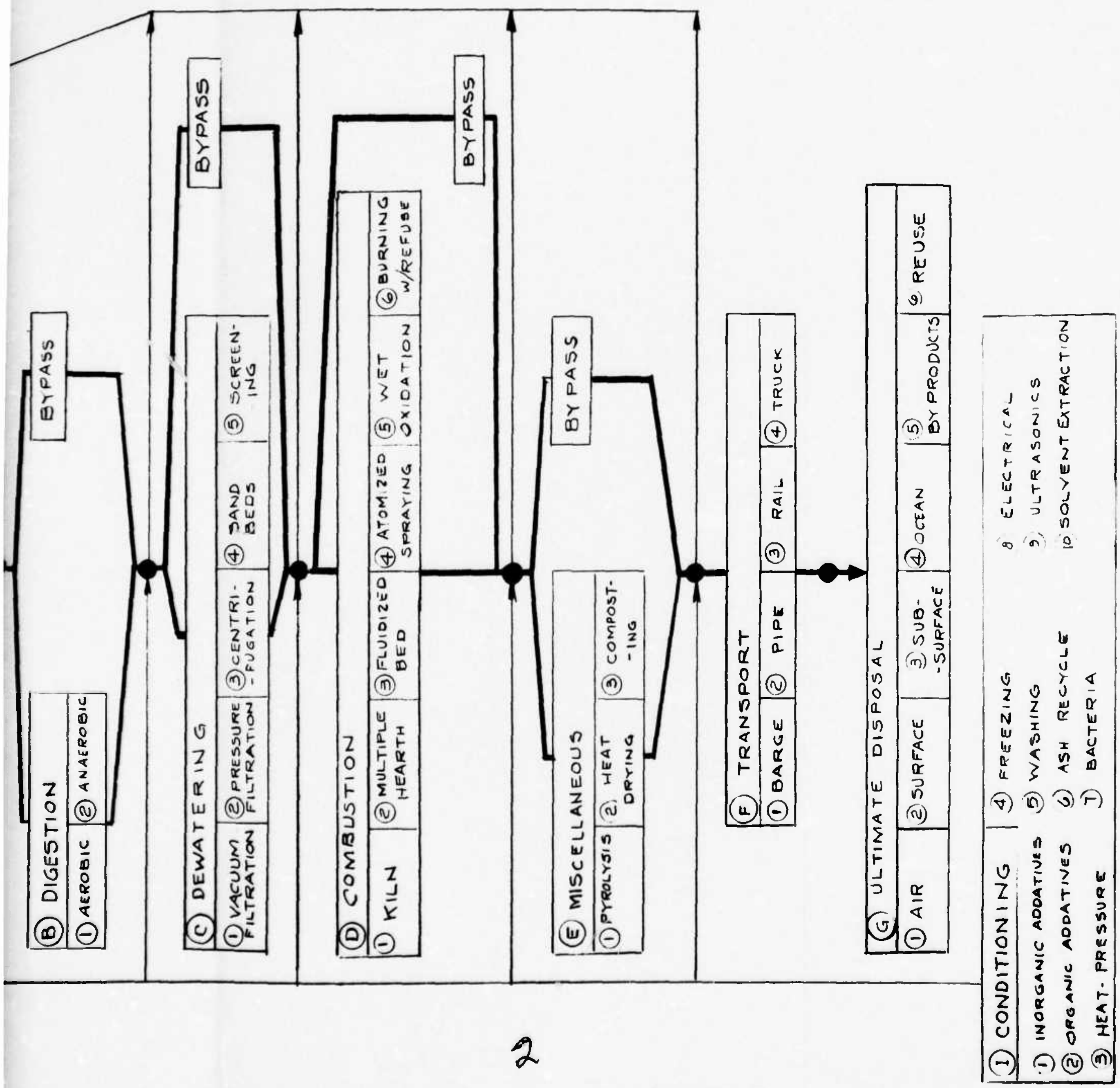
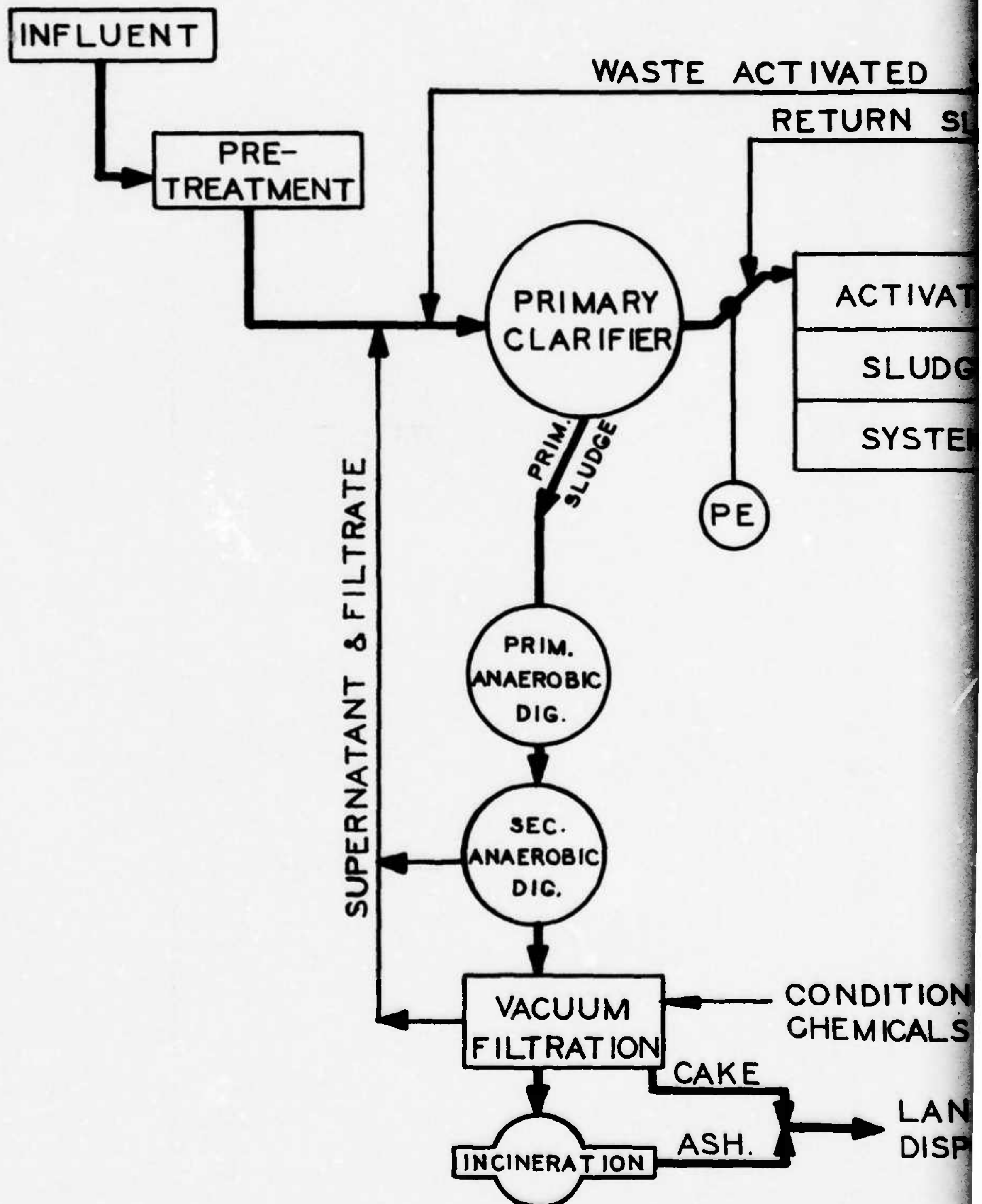


FIGURE 2

WASTE SOLIDS TREATMENT: UNIT PROCESS ALTERNATIVES



HAVENS AND EMERSON, LIMITED

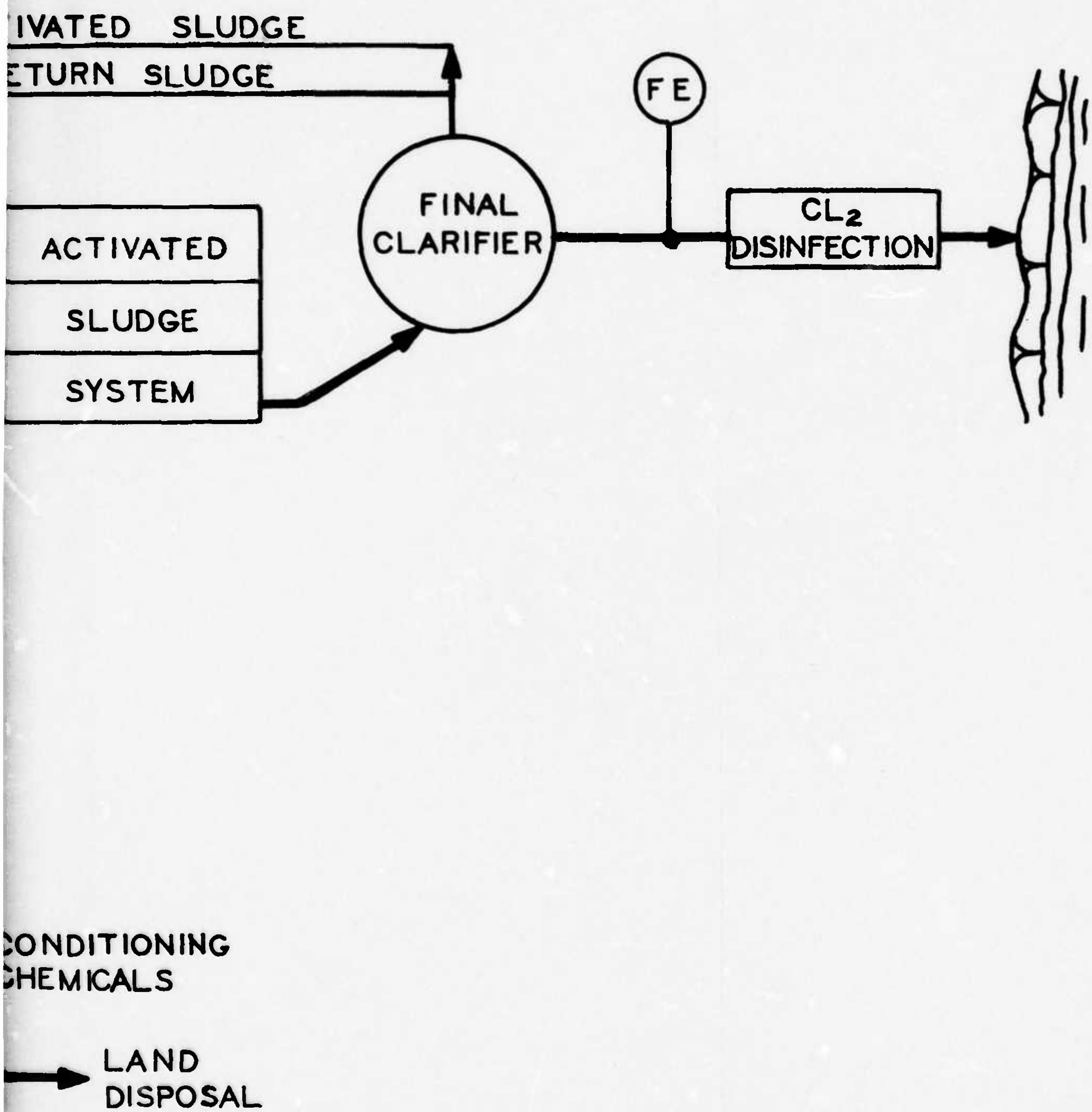
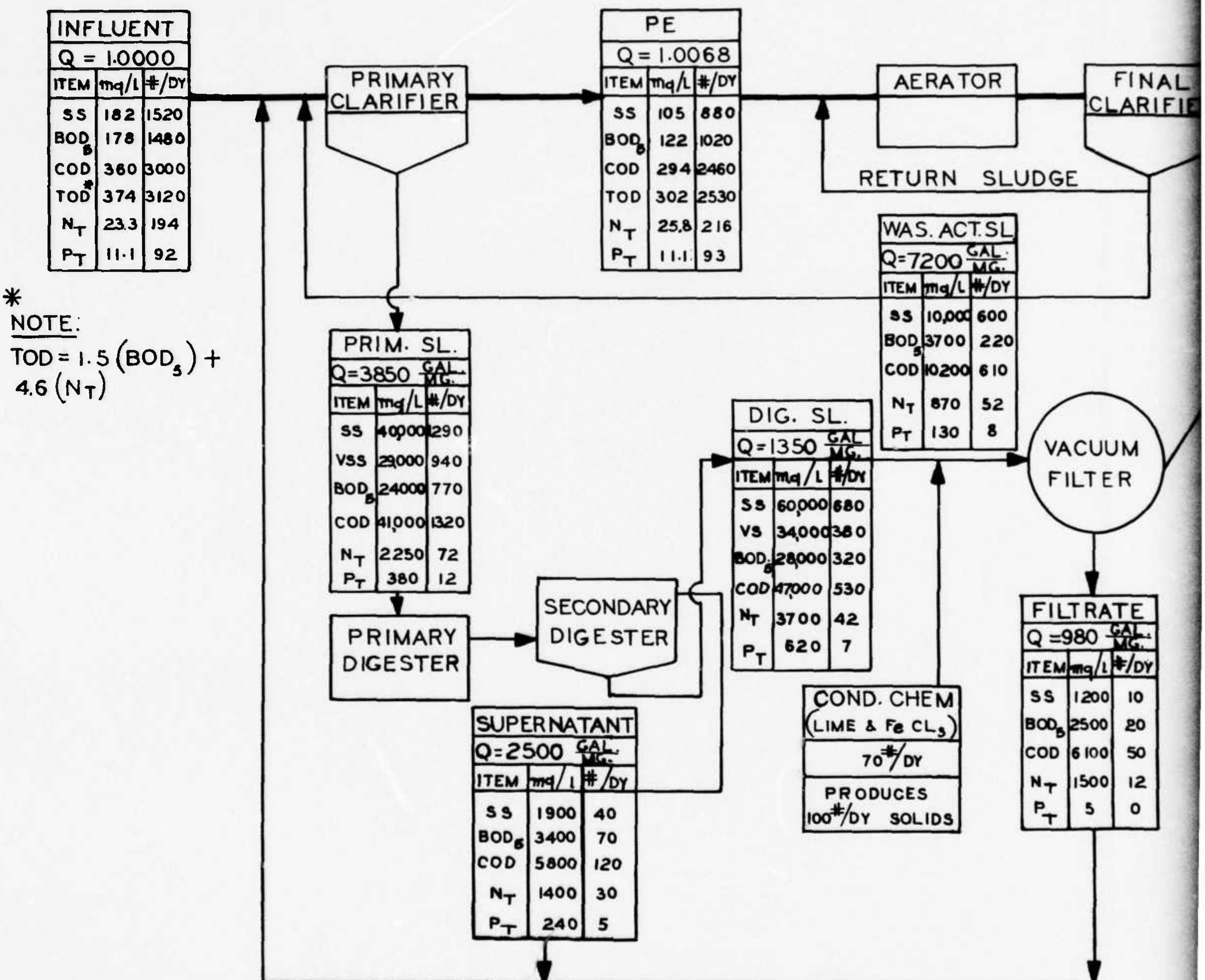
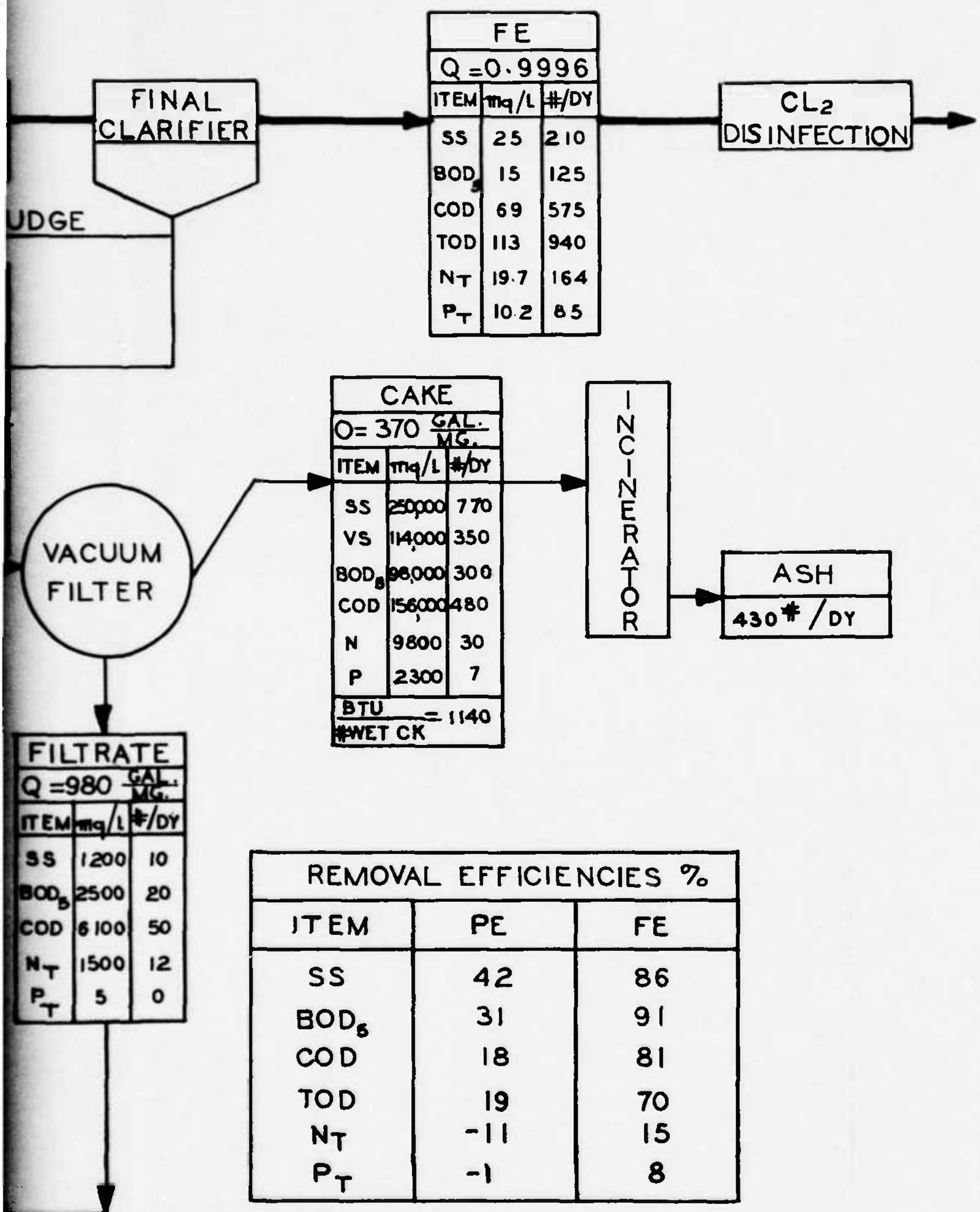


FIGURE 3
BASIC BIOLOGICAL TREATMENT SYSTEM

A 27



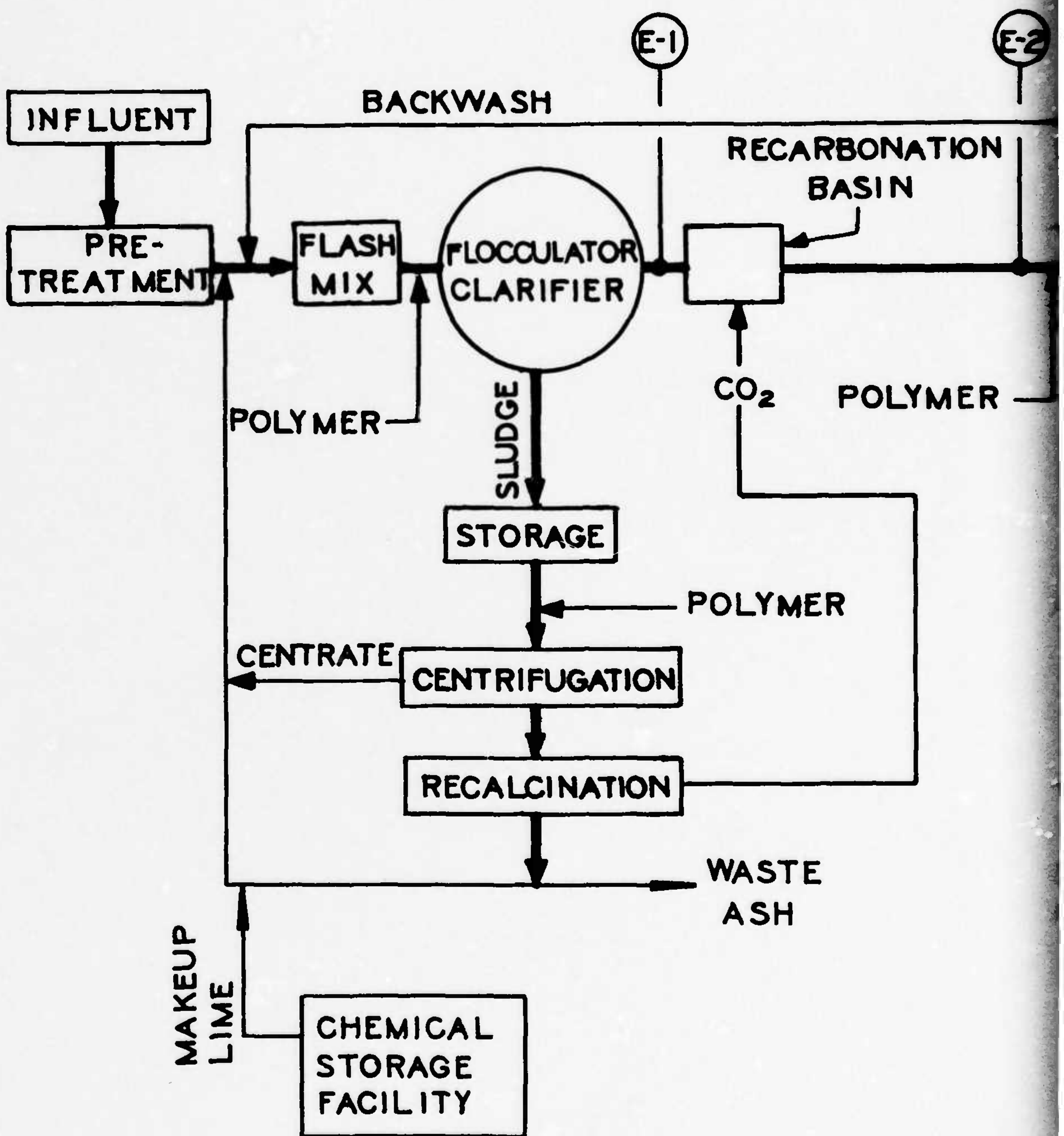
HAVENS AND EMERSON, LIMITED



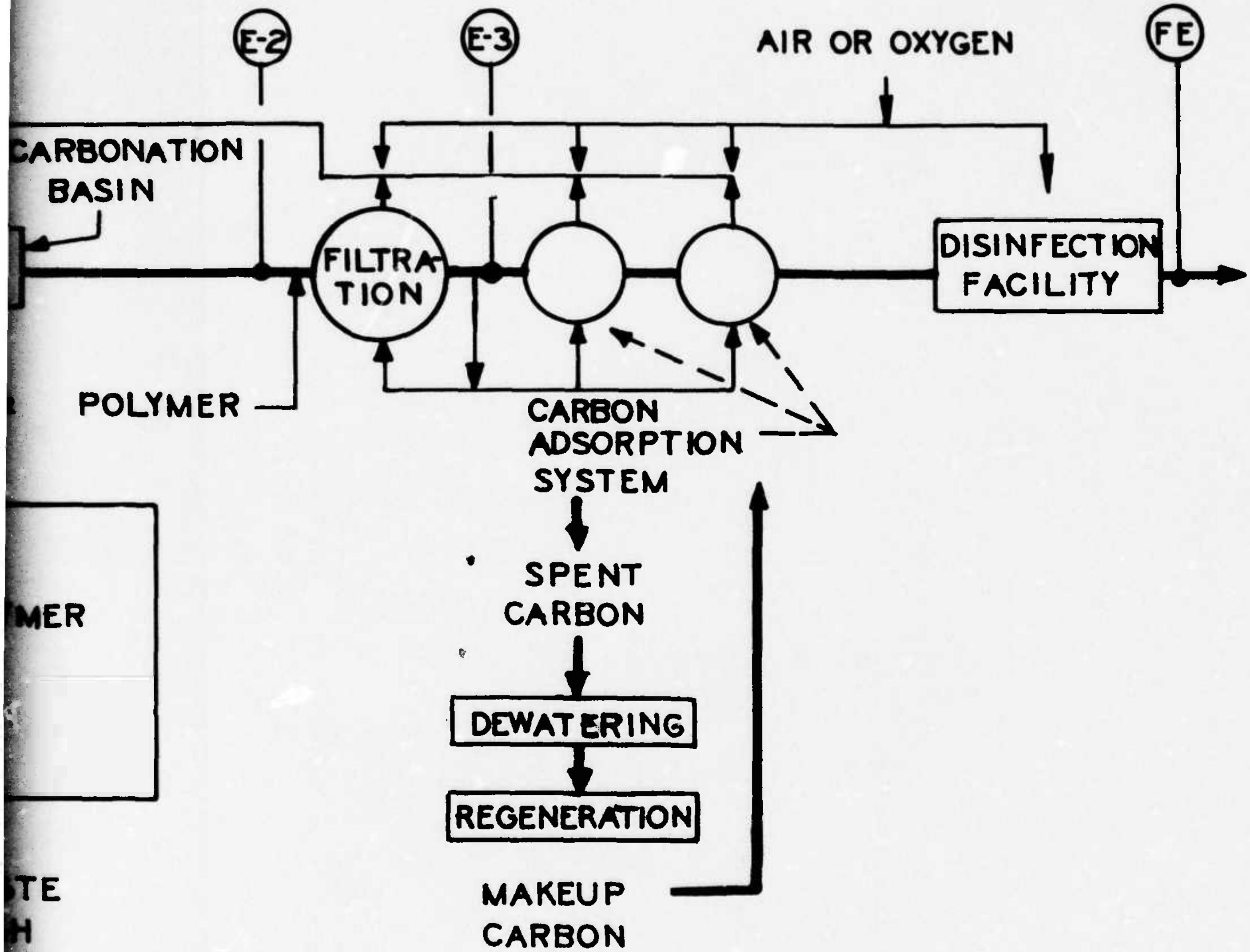
REMOVAL EFFICIENCIES %		
ITEM	PE	FE
SS	42	86
BOD_5	31	91
COD	18	81
TOD	19	70
N_T	-11	15
P_T	-1	8

2

FIGURE 3A
BASIC BIOLOGICAL TREATMENT SYSTEM
PROCESS PERFORMANCE


INFLUENT
PRE-TREATMENT
BACKWASH
E-1
E-2
FLASH MIX
FLOCCULATOR CLARIFIER
RECARBONATION BASIN
POLYMER
CO_2
POLYMER
SLUDGE
STORAGE
POLYMER
CENTRATE
CENTRIFUGATION
RECALCINATION
WASTE ASH
MAKEUP LIME
CHEMICAL STORAGE FACILITY

1

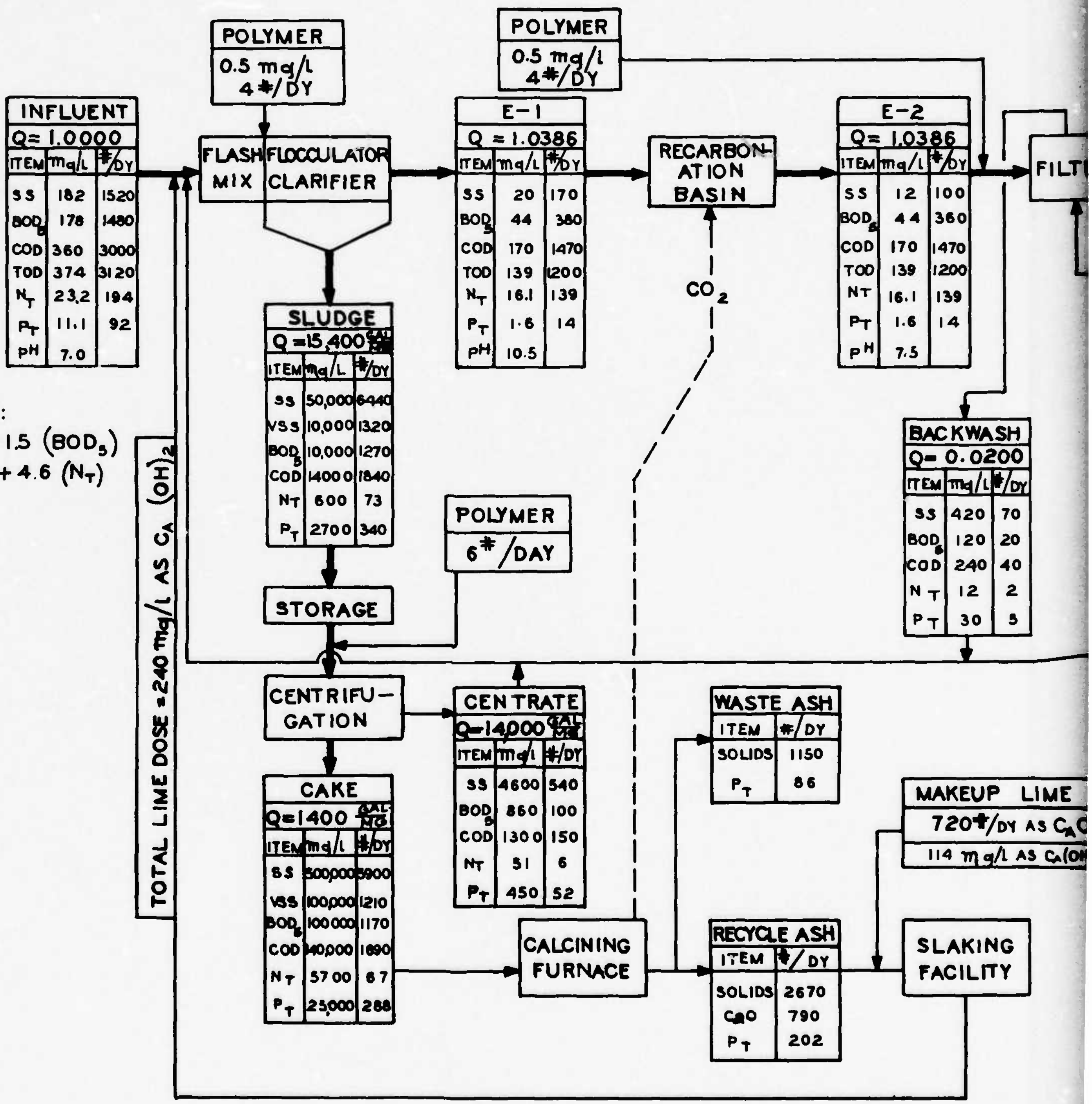


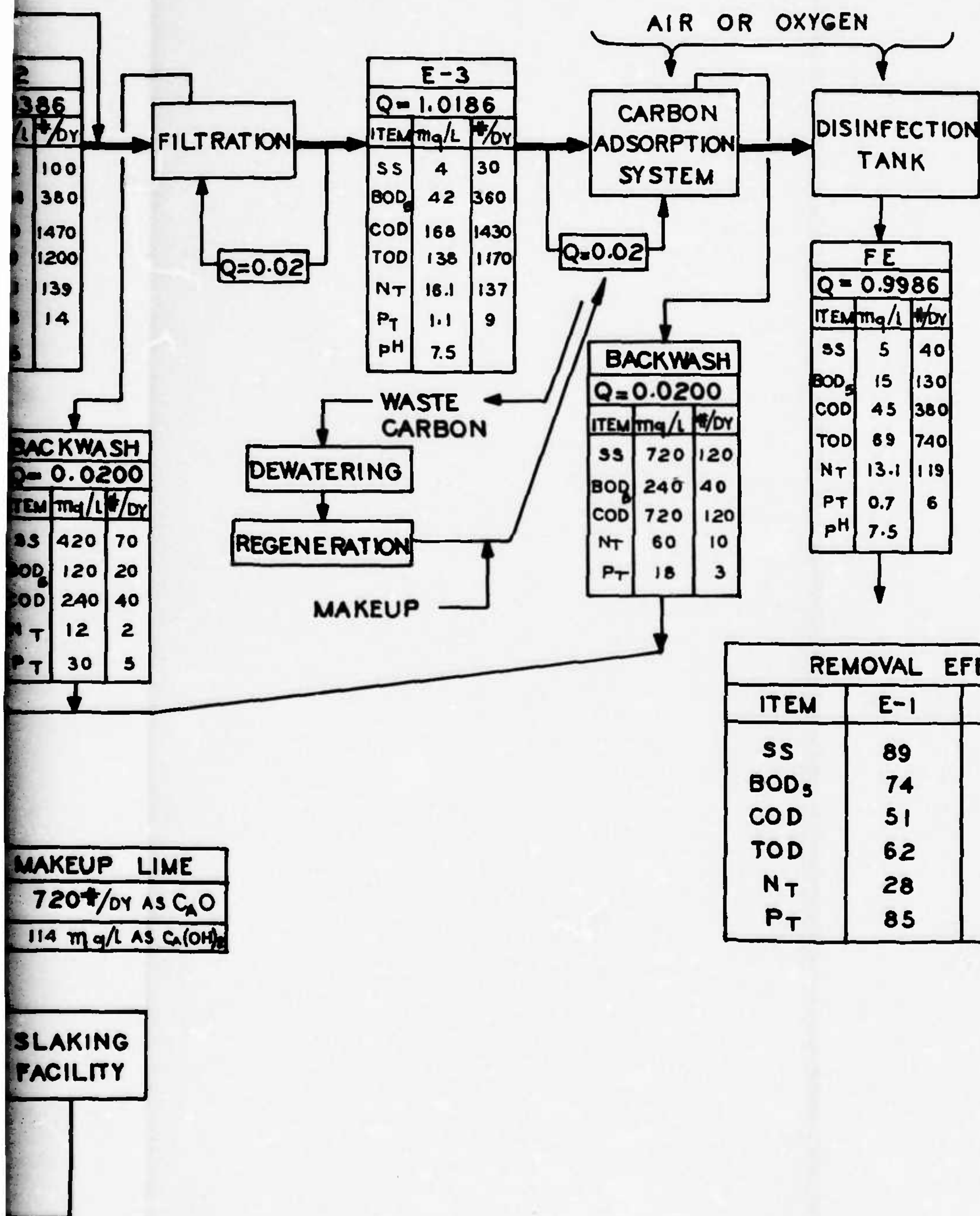
2

FIGURE 4

BASIC PHYSICAL-CHEMICAL TREATMENT SYSTEM

NOTE:
TOD = 1.5 (BOD_5) + 4.6 (N_T)



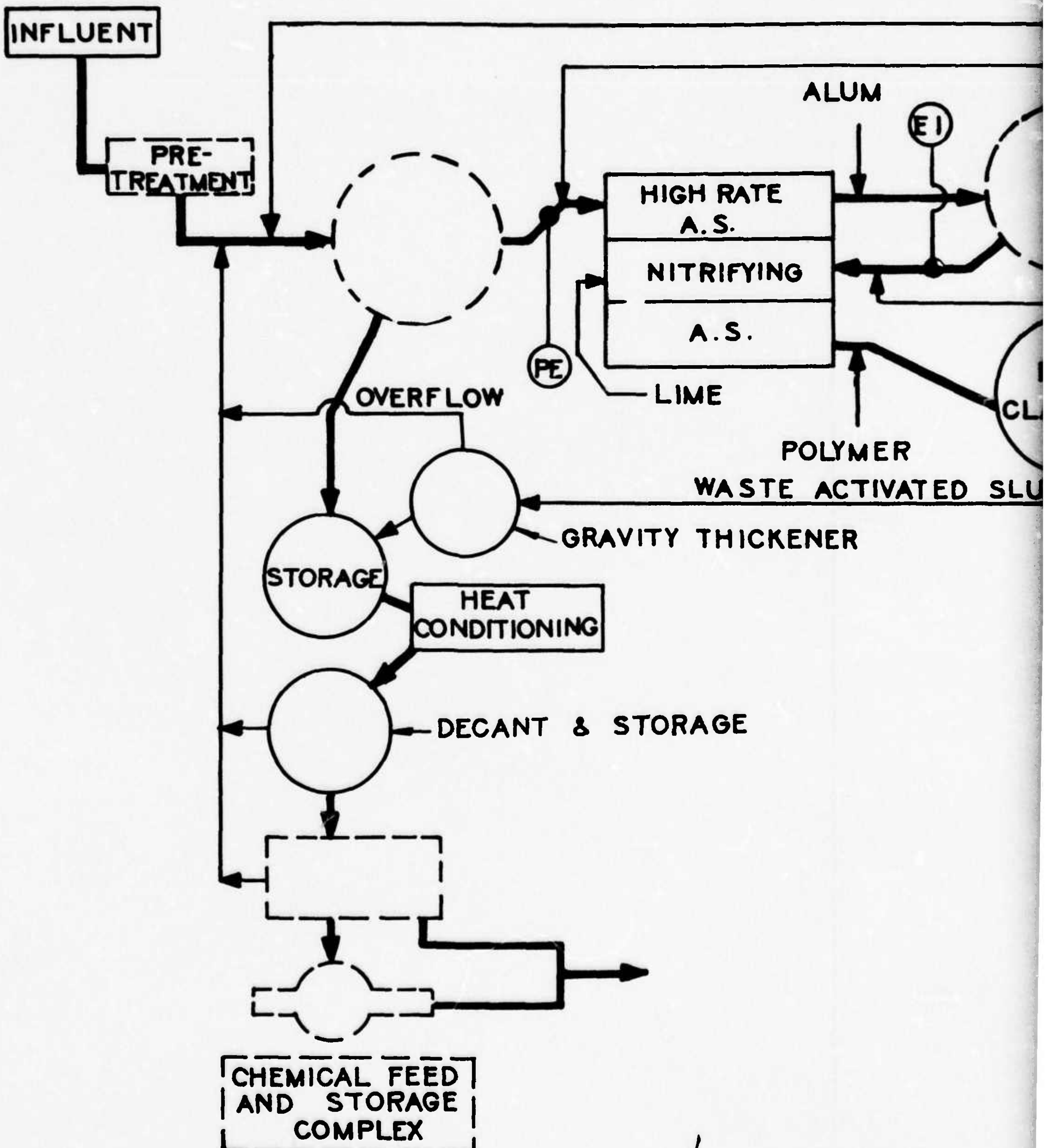


REMOVAL EFFICIENCIES — %				
ITEM	E-1	E-2	E-3	FE
SS	89	93	98	98
BOD_5	74	74	76	91
COD	51	51	52	87
TOD	62	62	62	76
N_T	28	28	29	39
P_T	85	85	90	93

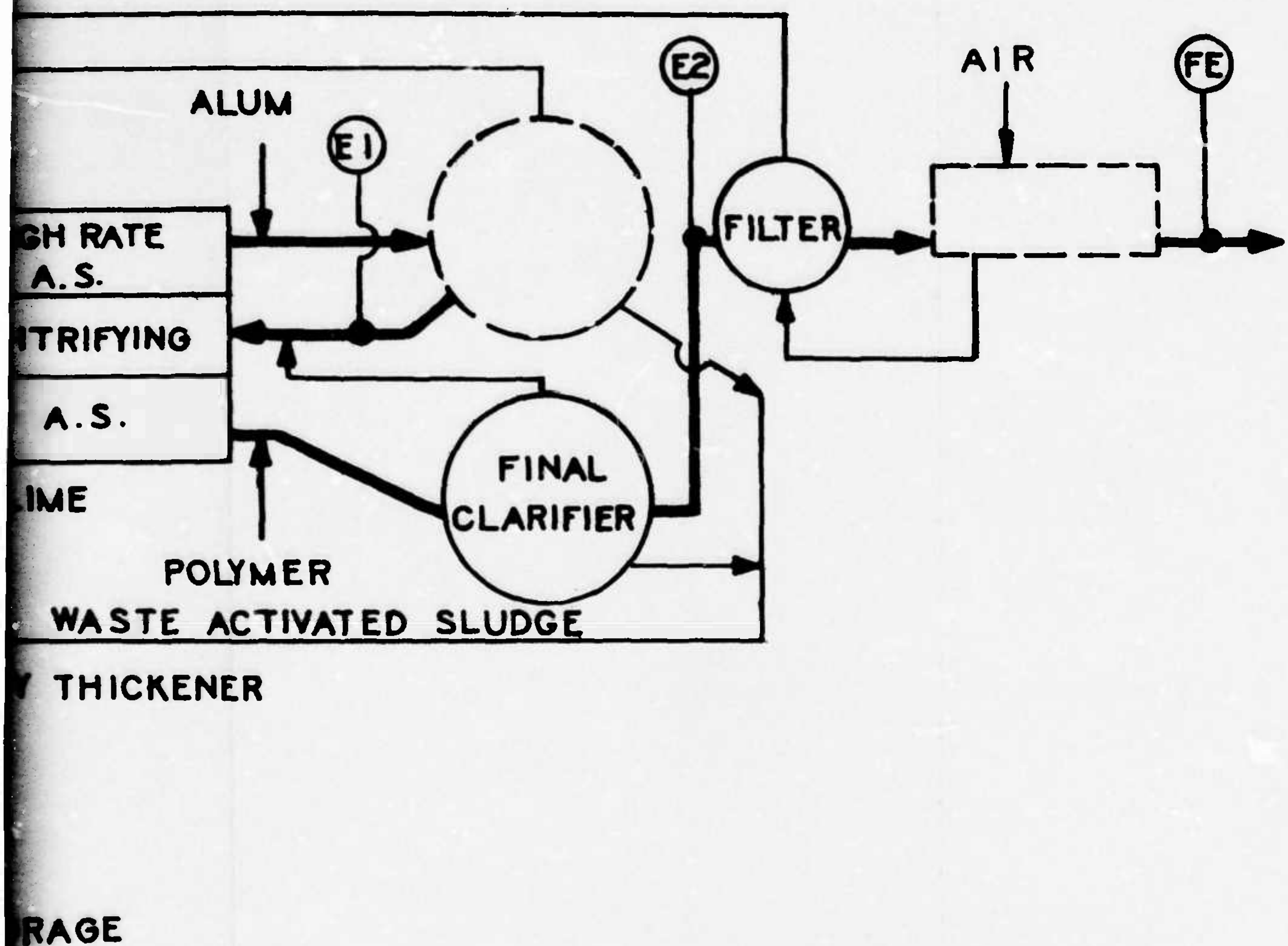
2

FIGURE 4A

BASIC PHYSICAL-CHEMICAL TREATMENT SYSTEM



HAVENS AND EMERSON, LIMITED

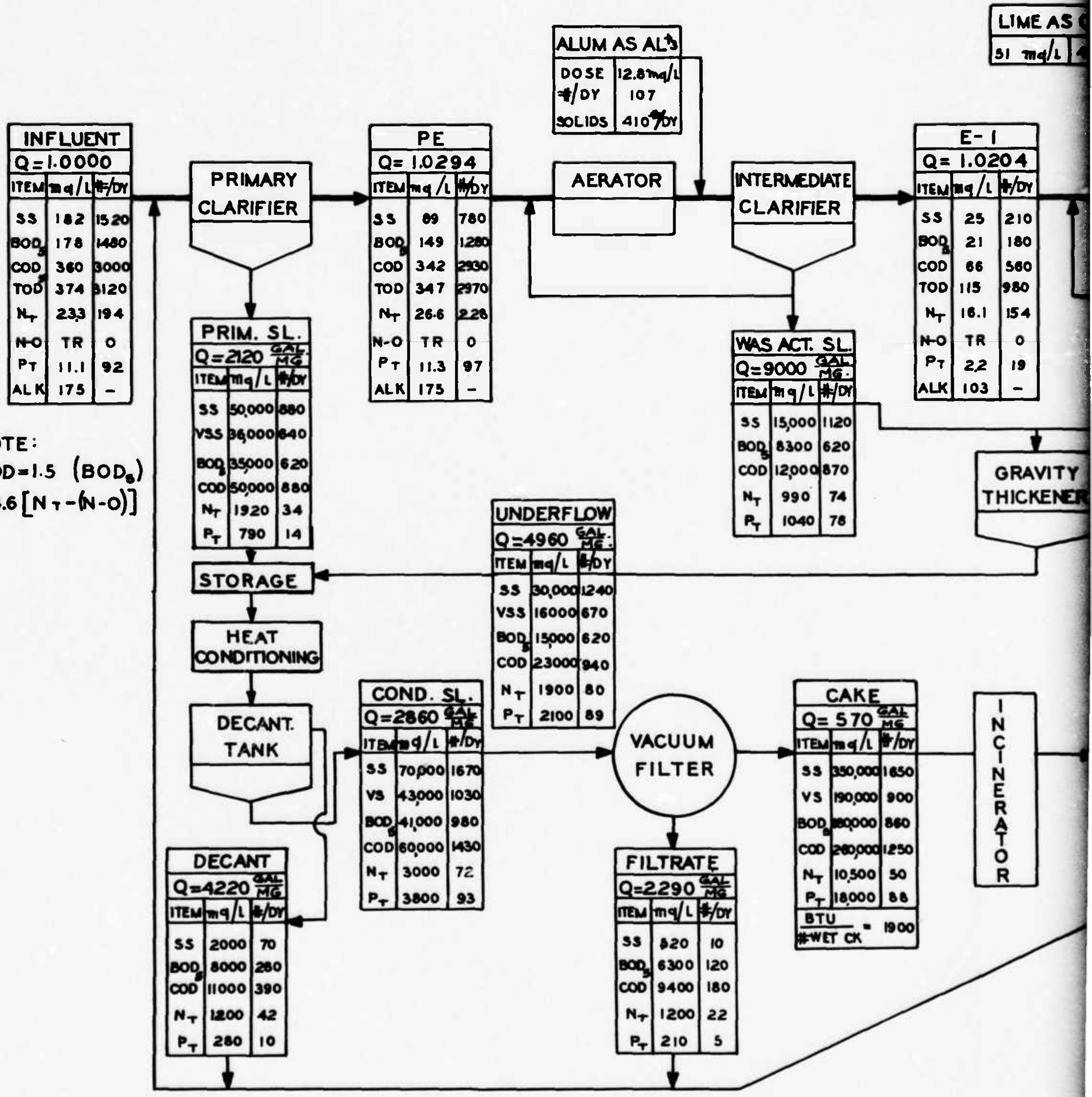


1

2

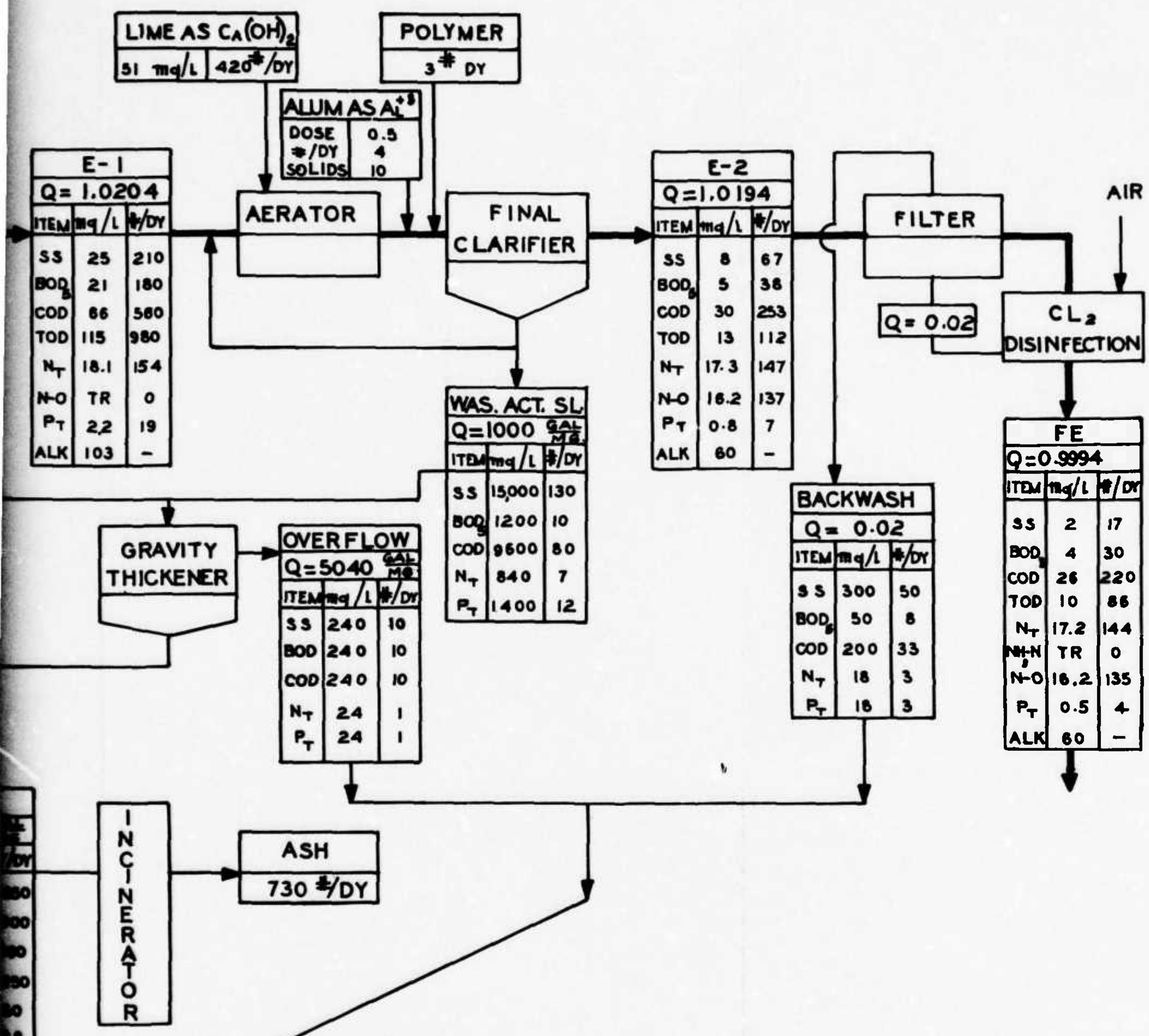
FIGURE 5

BASIC BIOLOGICAL TREATMENT SYSTEM UPGRADED TO MEET STATE EFFLUENT STANDARDS



* NOTE:
$TOD = 1.5\,(BOD_5) + 4.6\,[N_T - (N\text{-}O)]$

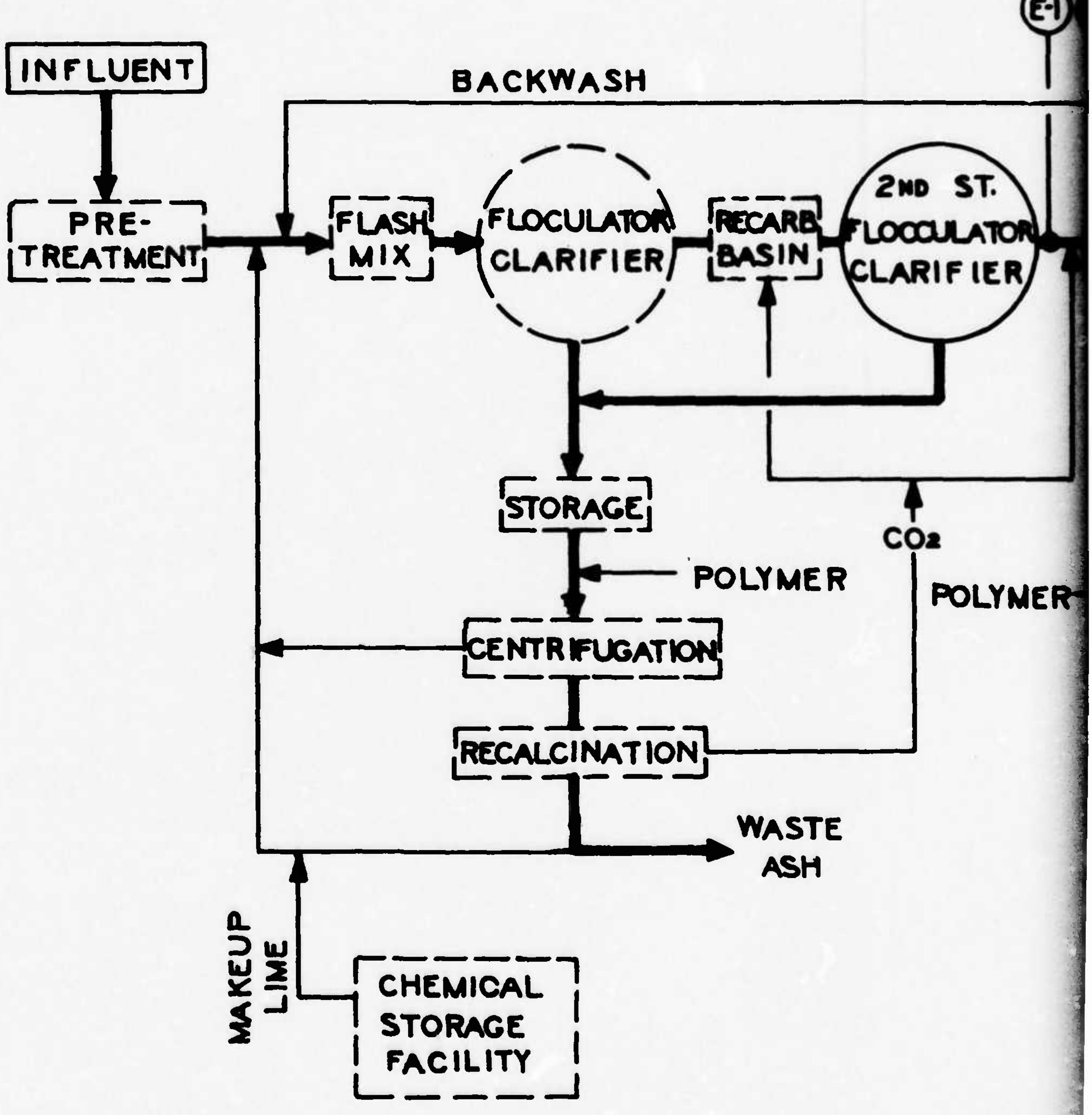
HAVENS AND EMERSON, LIMITED



REMOVAL EFFICIENCIES- %				
ITEM	PE	E-1	E-2	FE
SS	49	86	96	99
BOD_5	14	88	97	98
COD	2	81	92	93
TOD	5	69	96	97
N_T	-18	21	24	26
P_T	-5	80	92	96

2

FIGURE 5A
BASIC BIOLOGICAL TREATMENT SYSTEM UPGRADED TO MEET STATE EFFLUENT STANDARDS: PROCESS PERFORMANCE



HAVENS AND EMERSON, LIMITED

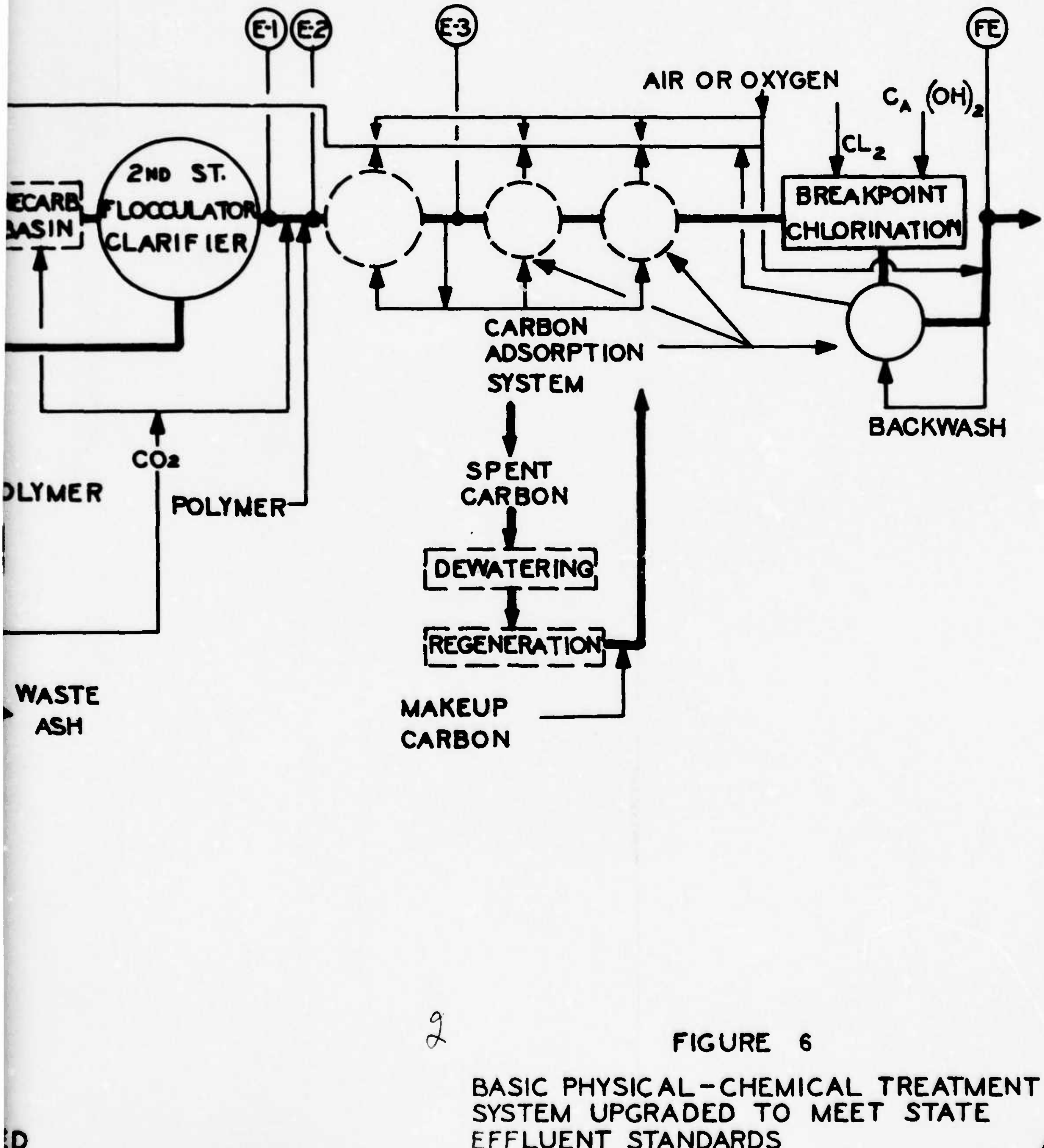


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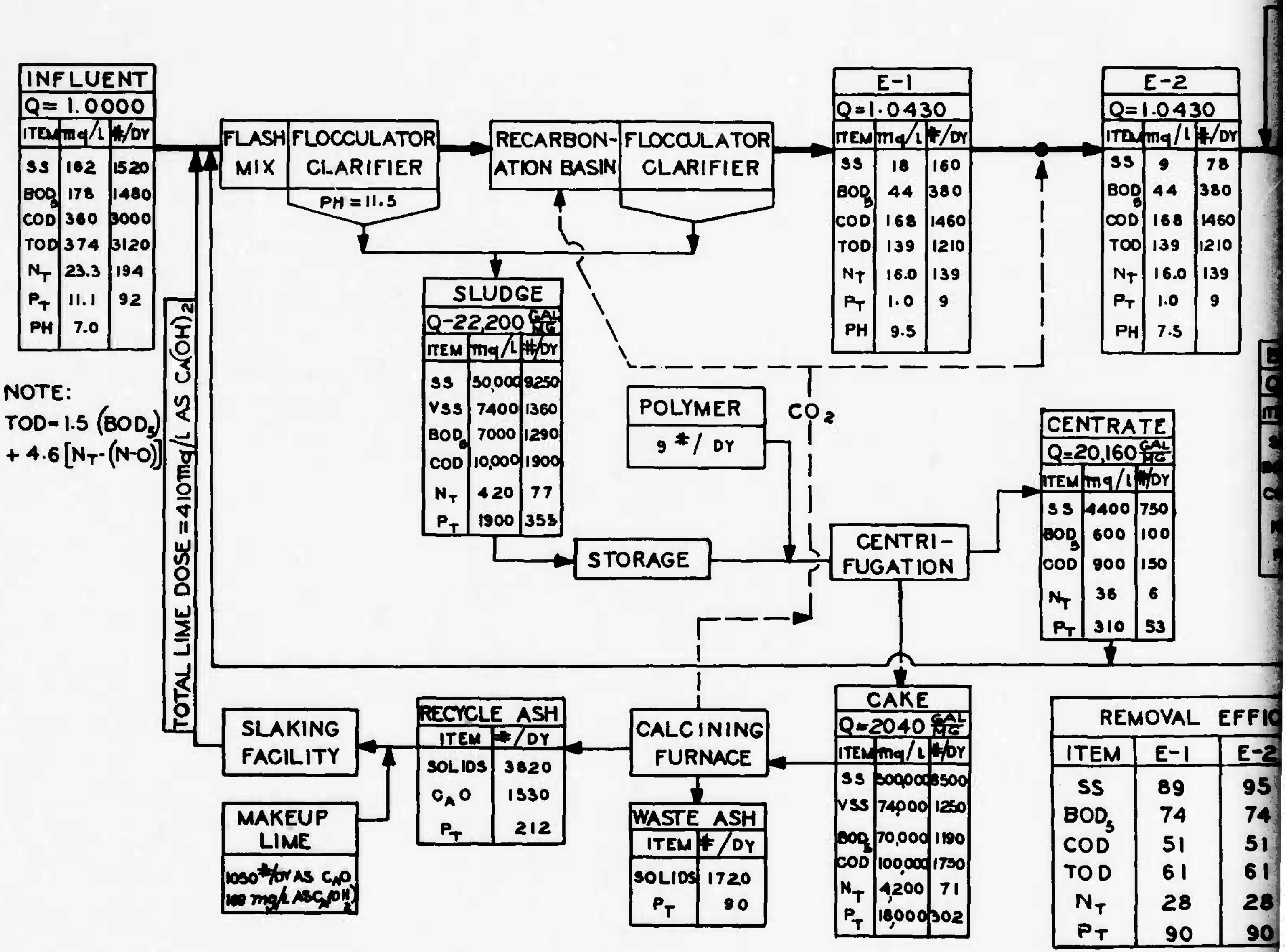
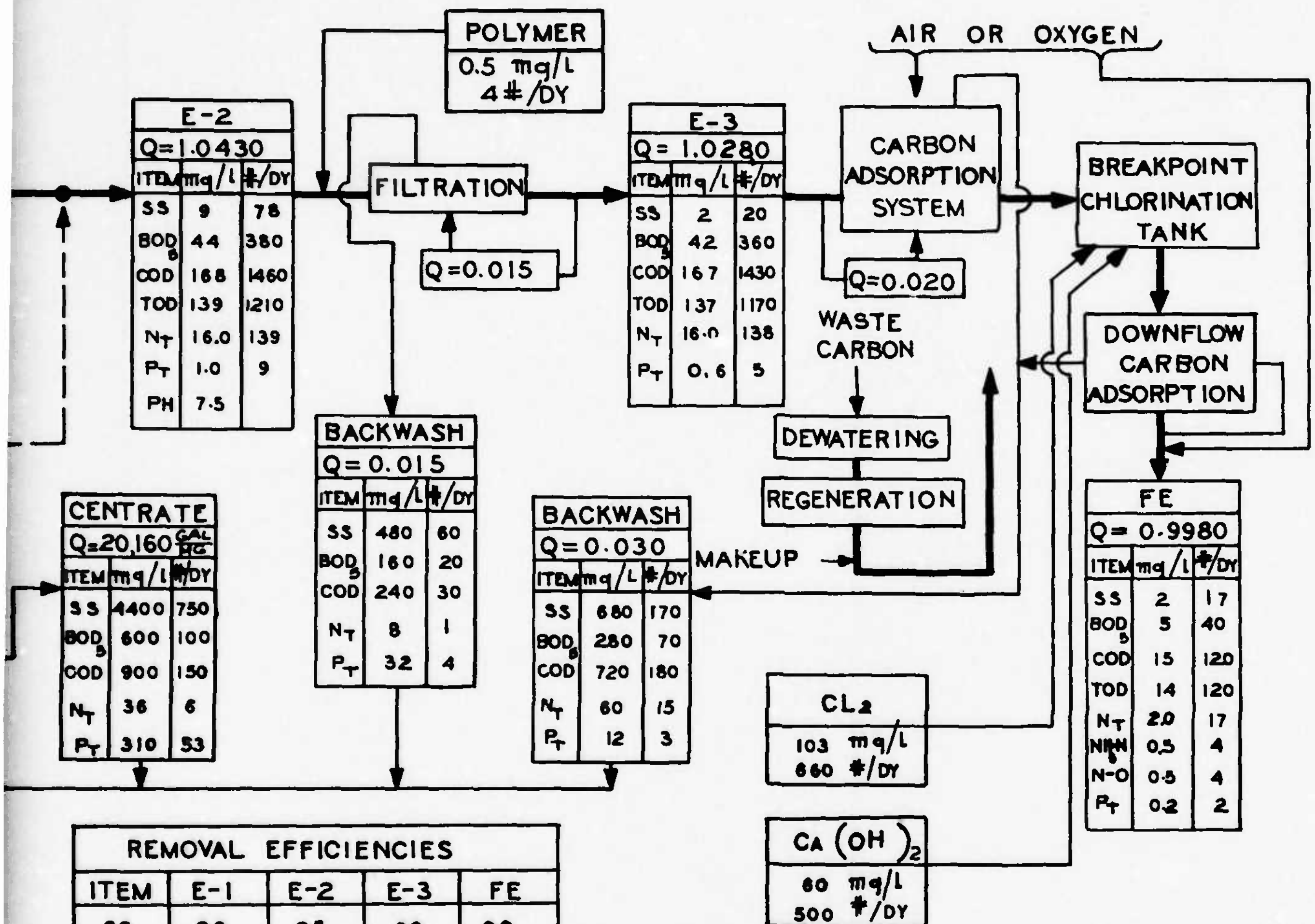
FIGURE 6

BASIC PHYSICAL-CHEMICAL TREATMENT SYSTEM UPGRADED TO MEET STATE EFFLUENT STANDARDS

A33



HAVENS AND EMERSON, LIMITED



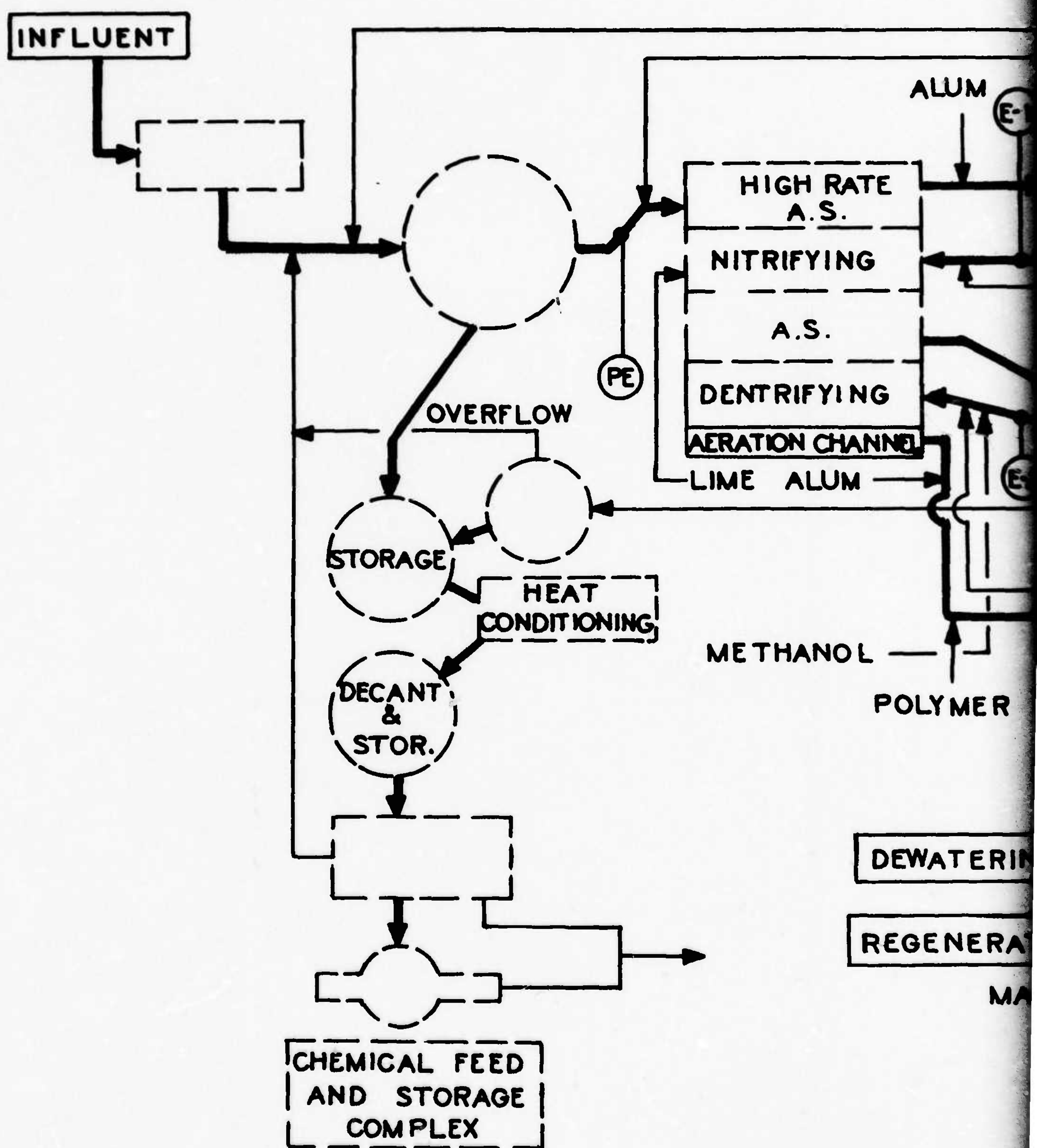
REMOVAL EFFICIENCIES

ITEM	E-1	E-2	E-3	FE
SS	89	95	99	99
BOD_5	74	74	76	97
COD	51	51	52	96
TOD	61	61	62	96
N_T	28	28	29	91
P_T	90	90	95	98

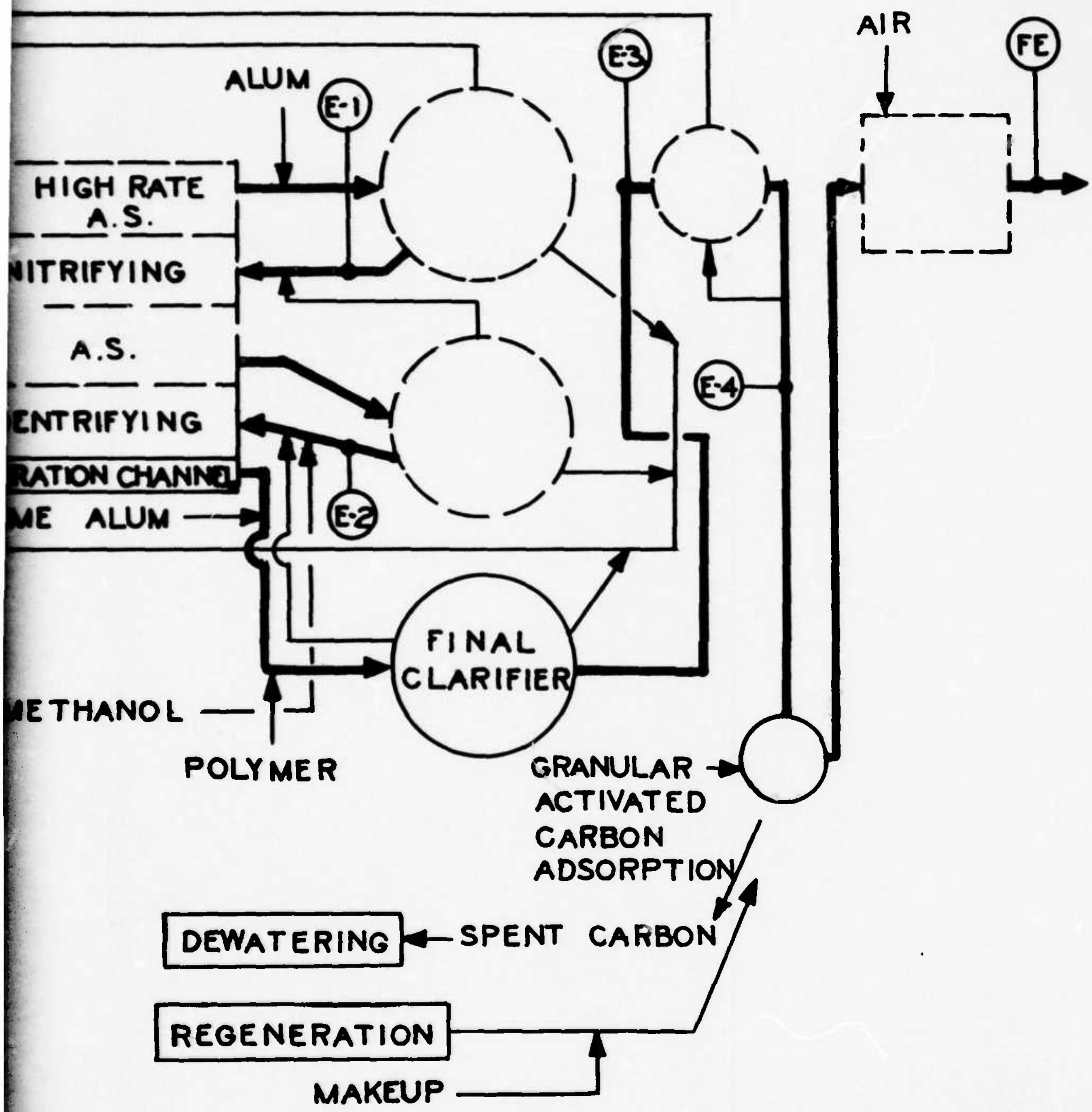
2

FIGURE 6A

BASIC PHYSICAL-CHEMICAL TREATMENT SYSTEM UPGRADED TO MEET STATE EFFLUENT STANDARDS: PROCESS PERFORMANCE



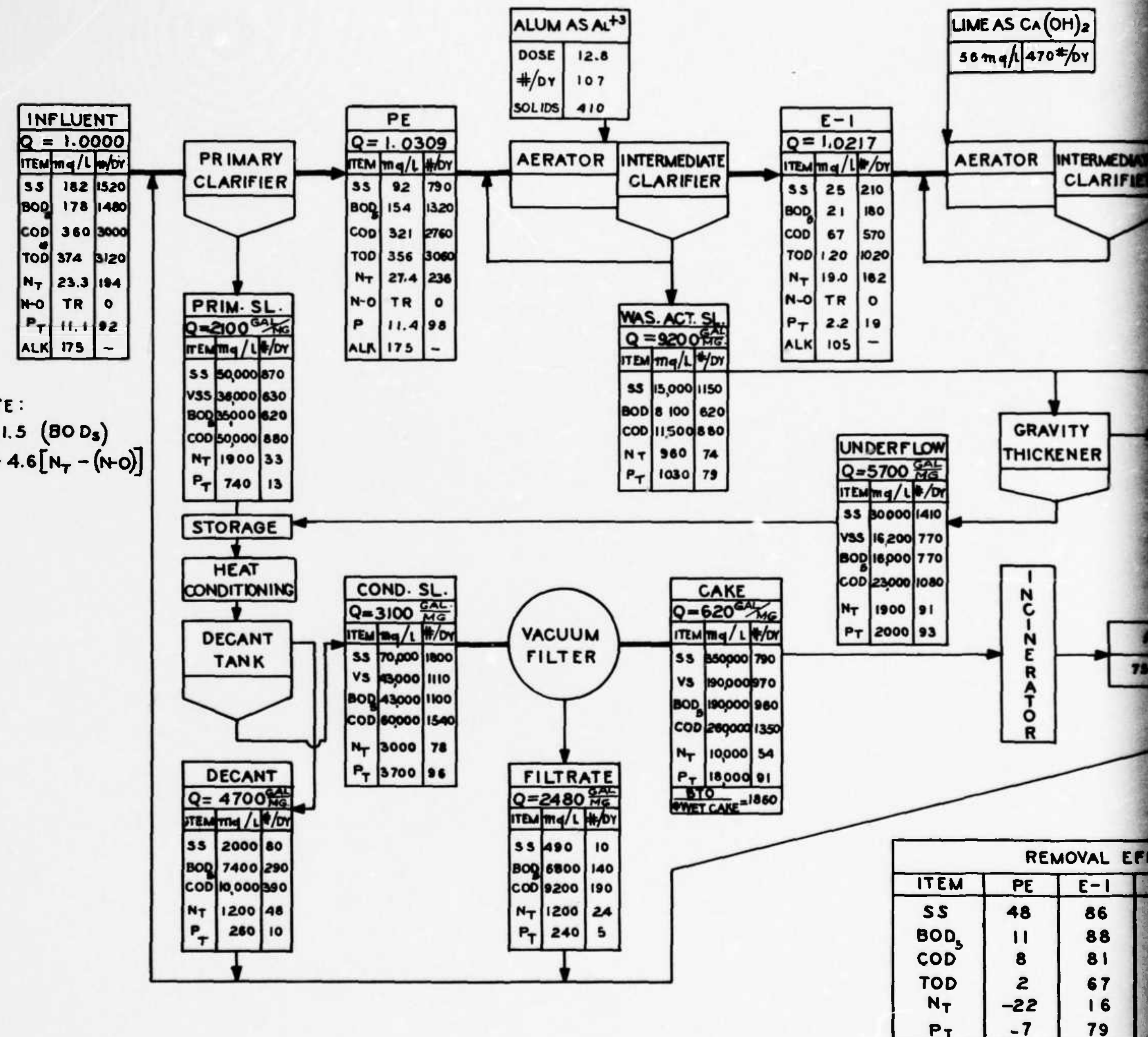
HAVENS AND EMERSON, LIMITED



2

FIGURE 7

BASIC BIOLOGICAL TREATMENT SYSTEM UPGRADED TO MEET FEDERAL EFFLUENT STANDARDS



INFLUENT — Q = 1.0000

ITEM	mg/L	#/DY
SS	182	1520
BOD_5	178	1480
COD	360	3000
TOD*	374	3120
N_T	23.3	194
N-O	TR	0
P_T	11.1	92
ALK	175	–

PE — Q = 1.0309

ITEM	mg/L	#/DY
SS	92	790
BOD_5	154	1320
COD	321	2760
TOD	356	3060
N_T	27.4	236
N-O	TR	0
P	11.4	98
ALK	175	–

ALUM AS Al^{+3}

DOSE	12.8
#/DY	107
SOLIDS	410

E-1 — Q = 1.0217

ITEM	mg/L	#/DY
SS	25	210
BOD_5	21	180
COD	67	570
TOD	120	1020
N_T	19.0	182
N-O	TR	0
P_T	2.2	19
ALK	105	–

LIME AS $Ca(OH)_2$

56 mg/l	470 #/DY

PRIM. SL. — Q = 2100 GAL/MG

ITEM	mg/L	#/DY
SS	50,000	870
VSS	36,000	630
BOD_5	35,000	620
COD	50,000	880
N_T	1900	33
P_T	740	13

WAS. ACT. SL. — Q = 9200 GAL/MG

ITEM	mg/L	#/DY
SS	15,000	1150
BOD	8 100	620
COD	11,500	880
N_T	960	74
P_T	1030	79

UNDERFLOW — Q = 5700 GAL/MG

ITEM	mg/L	#/DY
SS	30000	1410
VSS	16,200	770
BOD_5	16,000	770
COD	23,000	1080
N_T	1900	91
P_T	2000	93

COND. SL. — Q = 3100 GAL/MG

ITEM	mg/L	#/DY
SS	70,000	1800
VS	43,000	1110
BOD_5	43,000	1100
COD	60,000	1540
N_T	3000	78
P_T	3700	96

CAKE — Q = 620 GAL/MG

ITEM	mg/L	#/DY
SS	350,000	790
VS	190,000	970
BOD_5	190,000	960
COD	260,000	1350
N_T	10,000	54
P_T	18,000	91

BTU / # WET CAKE = 1860

DECANT — Q = 4700 GAL/MG

ITEM	mg/L	#/DY
SS	2000	80
BOD_5	7400	290
COD	10,000	390
N_T	1200	48
P_T	260	10

FILTRATE — Q = 2480 GAL/MG

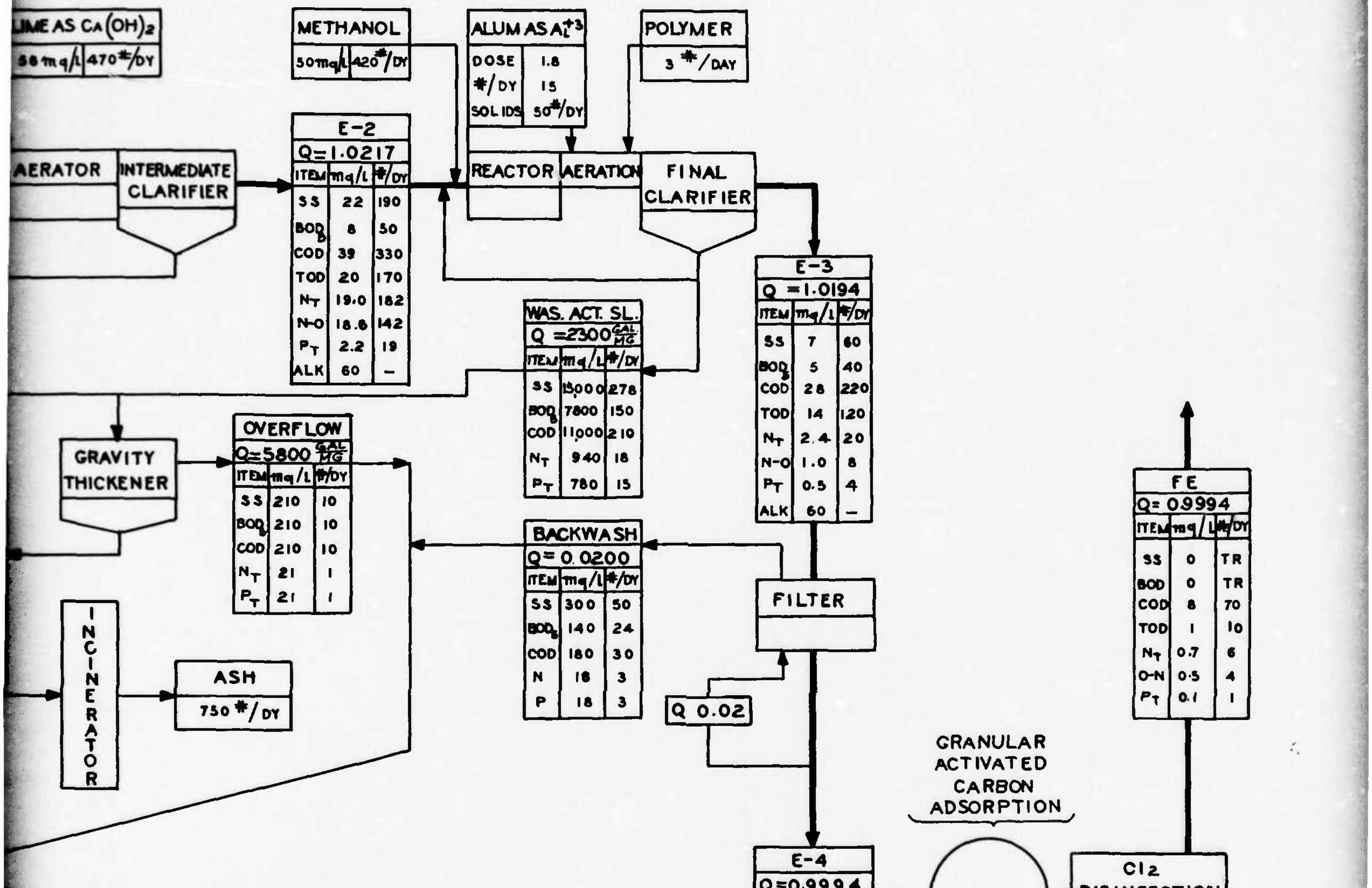
ITEM	mg/L	#/DY
SS	490	10
BOD_5	6800	140
COD	9200	190
N_T	1200	24
P_T	240	5

REMOVAL EF

ITEM	PE	E-1
SS	48	86
BOD_5	11	88
COD	8	81
TOD	2	67
N_T	-22	16
P_T	-7	79

*NOTE:

$$TOD = 1.5\,(BOD_5) + 4.6\,[N_T - (N\text{-}O)]$$

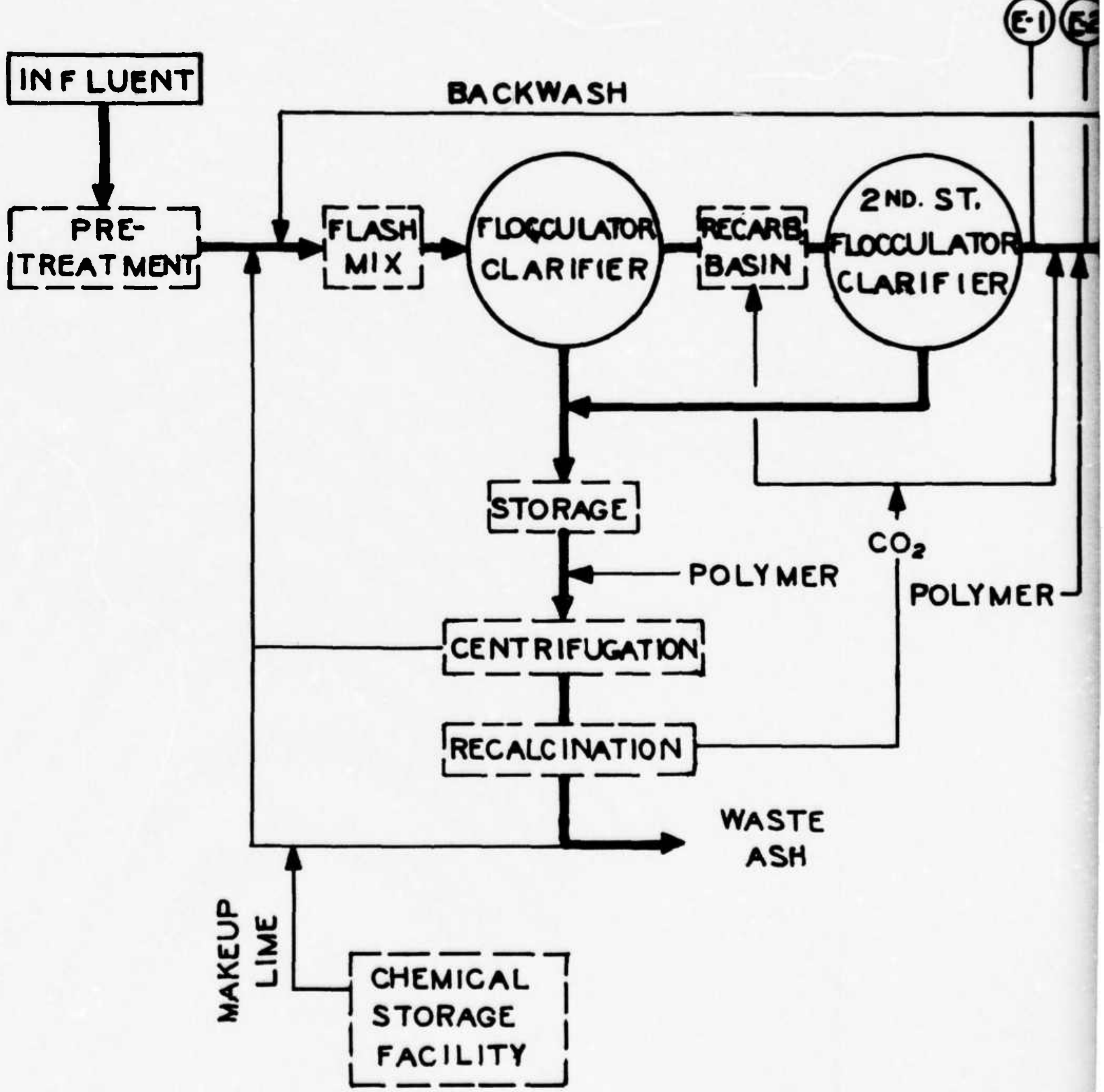


REMOVAL EFFICIENCIES %

M	PE	E-1	E-2	E-3	E-4	FE
	48	86	88	97	99	100
	11	88	97	98	99	100
	8	81	89	93	94	98
	2	67	94	96	98	99+
	-22	16	16	90	91	97
	-7	79	79	96	99	99+

2

FIGURE 7A
BASIC BIOLOGICAL TREATMENT SYSTEM UPGRADED TO MEET FEDERAL EFFLUENT STANDARDS PROCESS PERFORMANCE



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HAVENS AND EMERSON, LIMITED

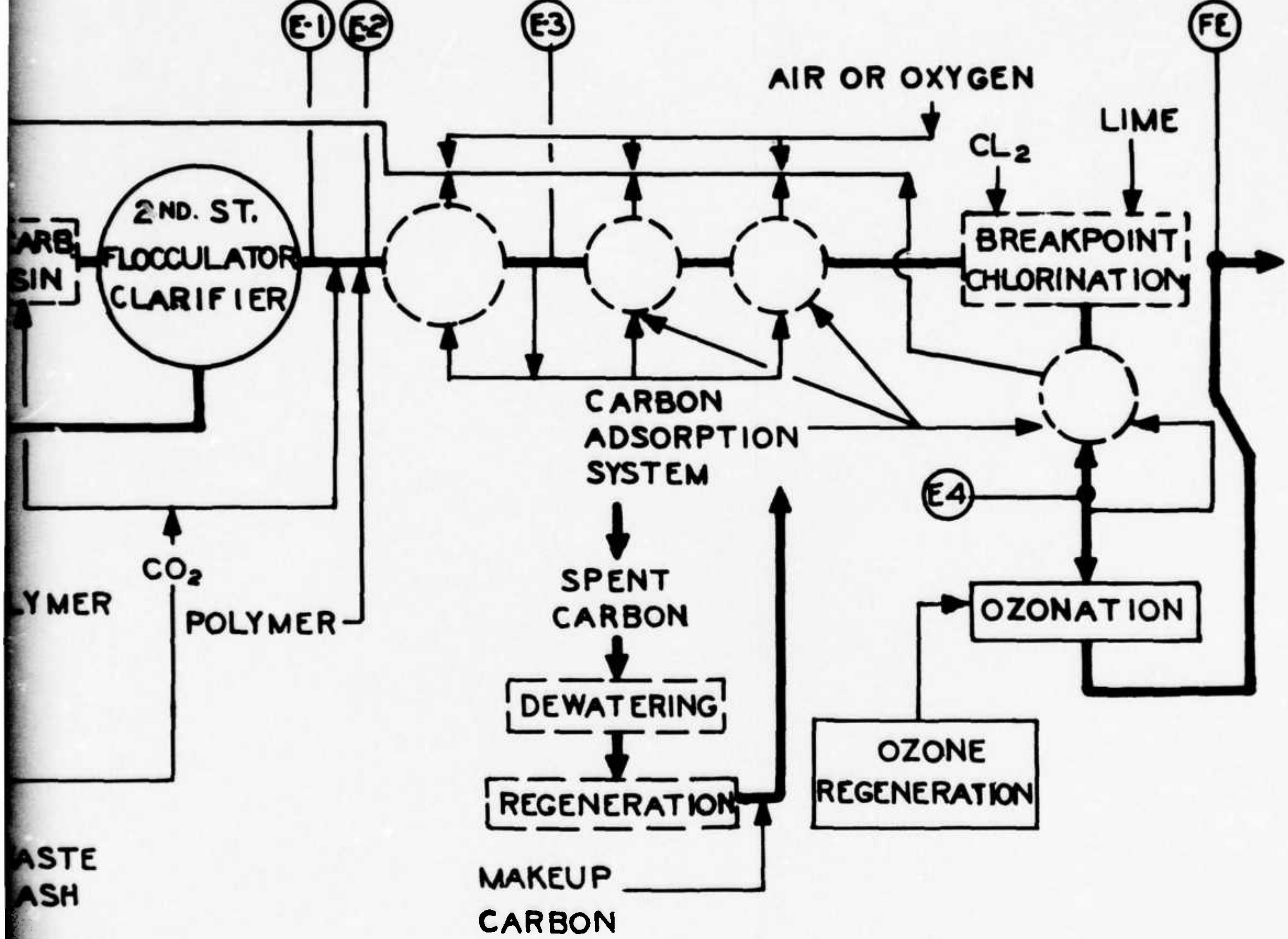

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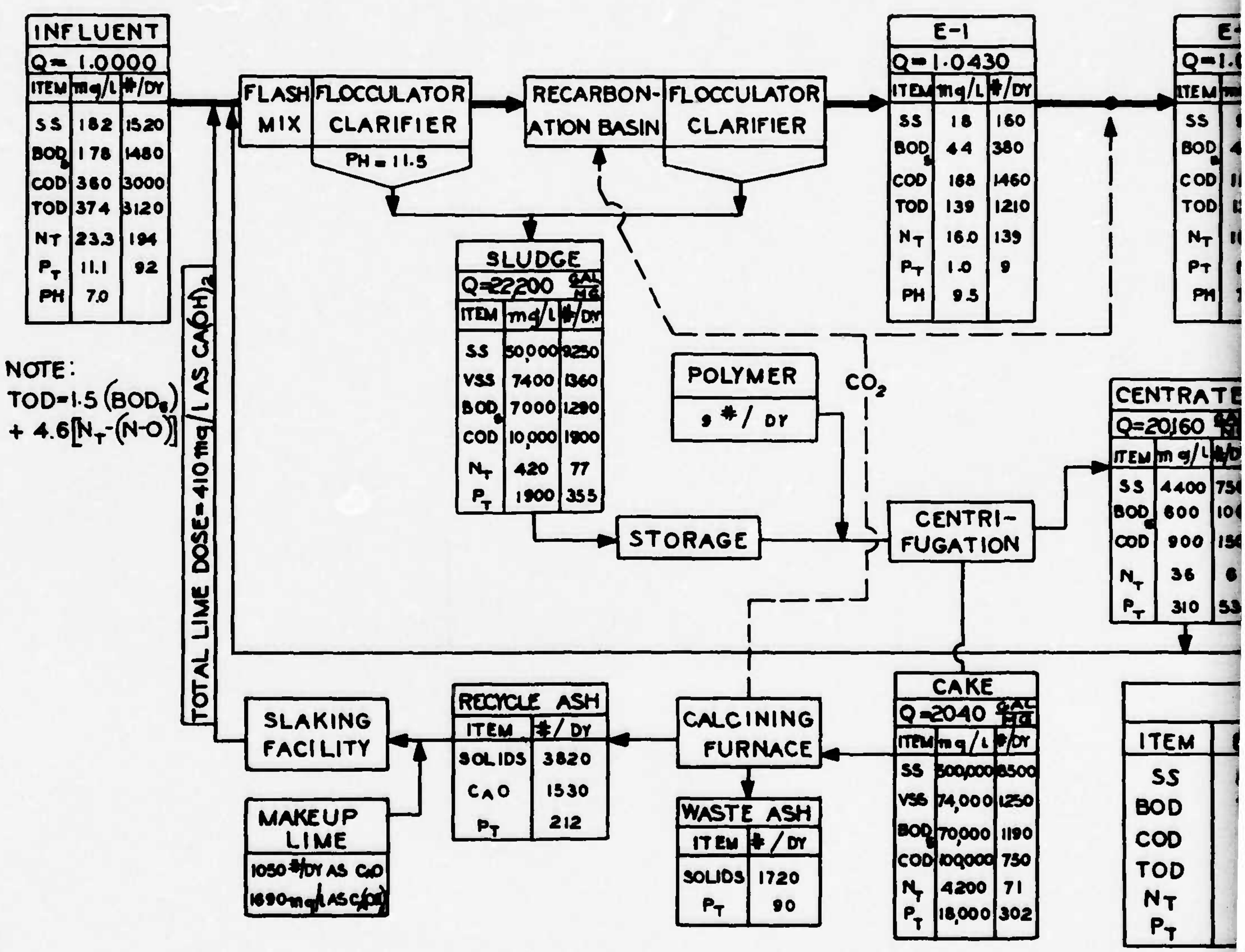
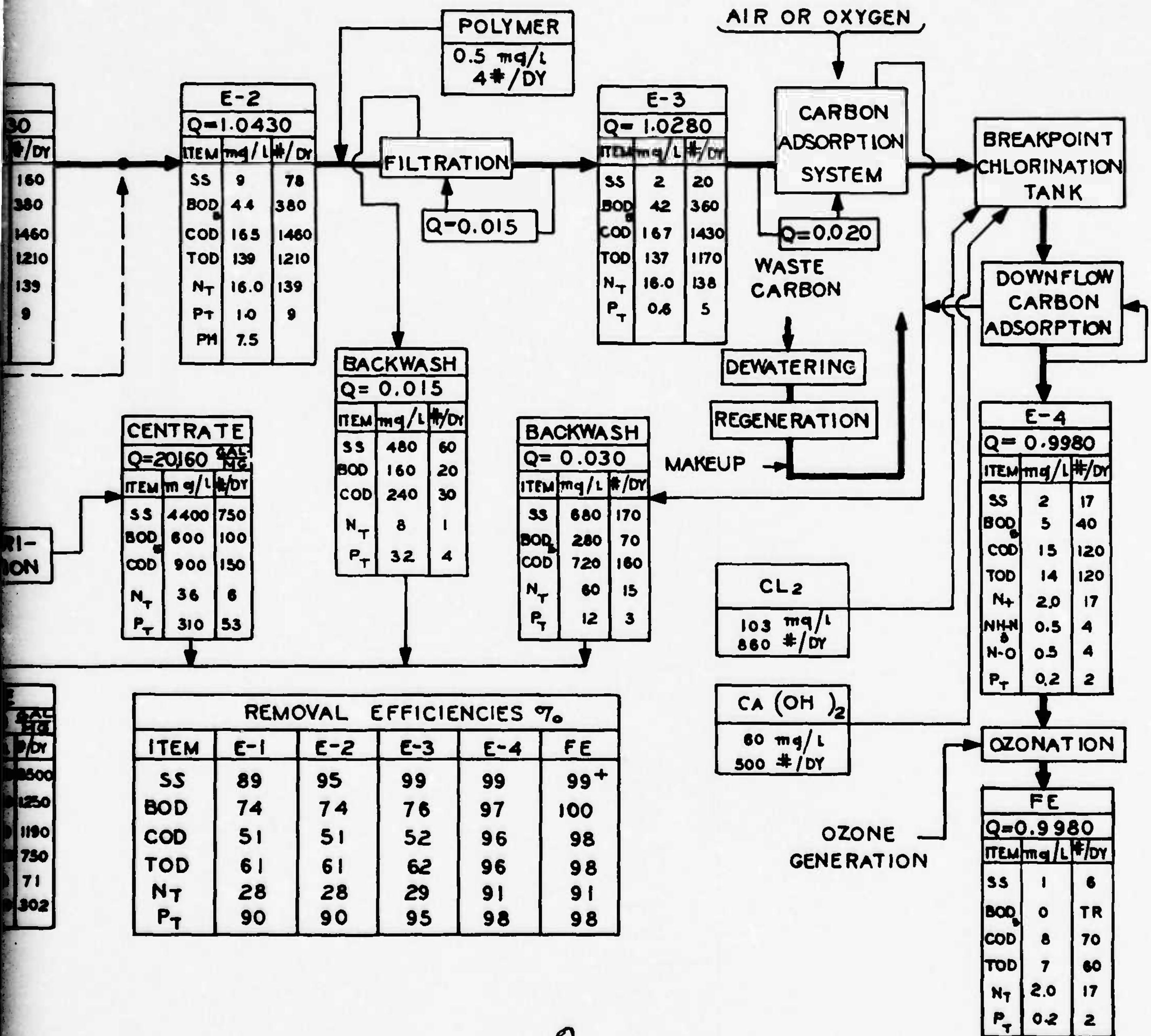
FIGURE 8

BASIC PHYSICAL-CHEMICAL TREATMENT SYSTEM UPGRADED TO MEET FEDERAL EFFLUENT STANDARDS

A37



HAVENS AND EMERSON, LIMITED



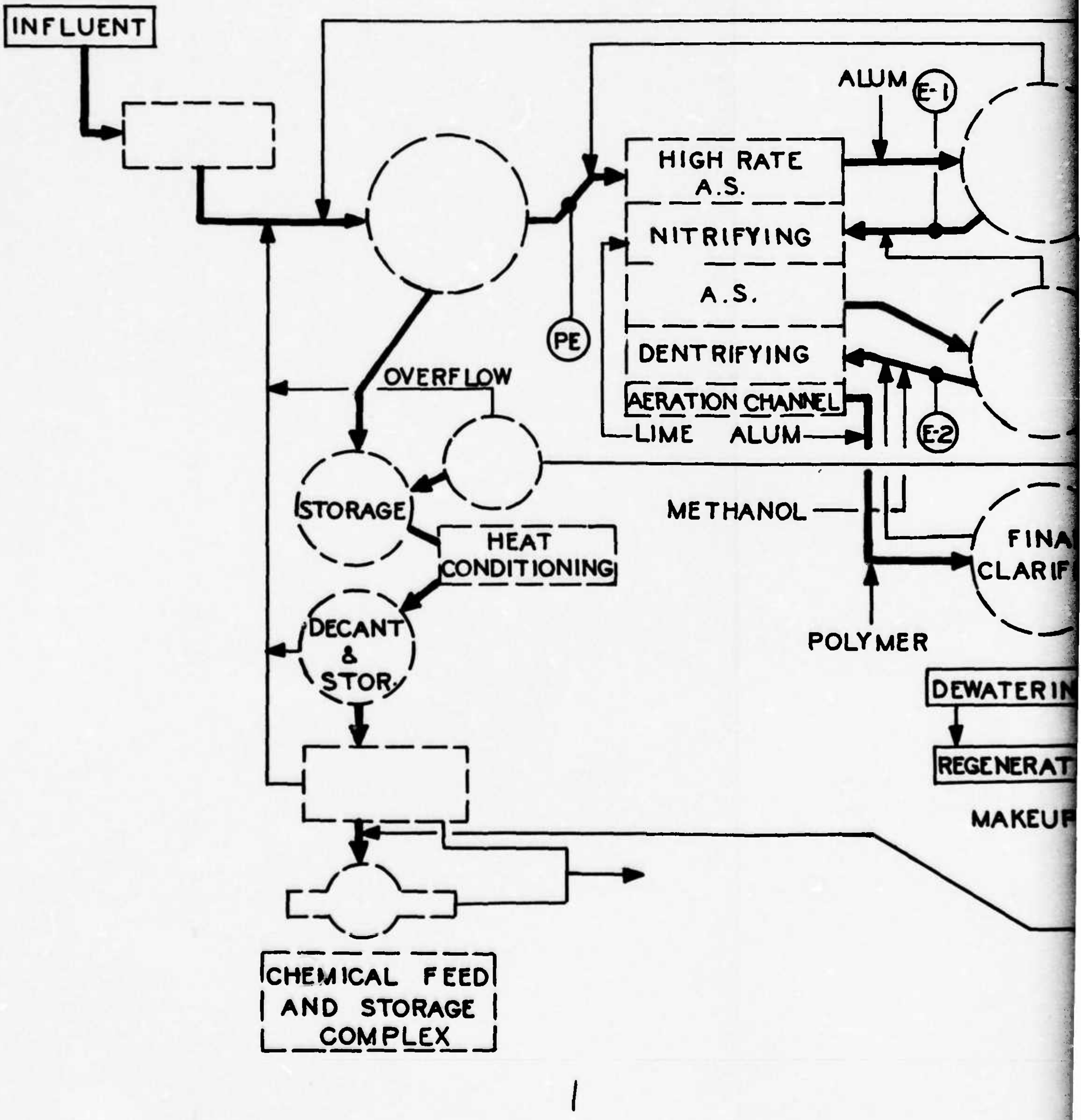
REMOVAL EFFICIENCIES %

ITEM	E-1	E-2	E-3	E-4	FE
SS	89	95	99	99	99+
BOD	74	74	76	97	100
COD	51	51	52	96	98
TOD	61	61	62	96	98
N_T	28	28	29	91	91
P_T	90	90	95	98	98

2

FIGURE 8A

BASIC PHYSICAL-CHEMICAL TREATMENT SYSTEM UPGRADED TO MEET FEDERAL EFFLUENT STANDARDS: PROCESS PERFORMANCE



HAVENS AND EMERSON, LIMITED

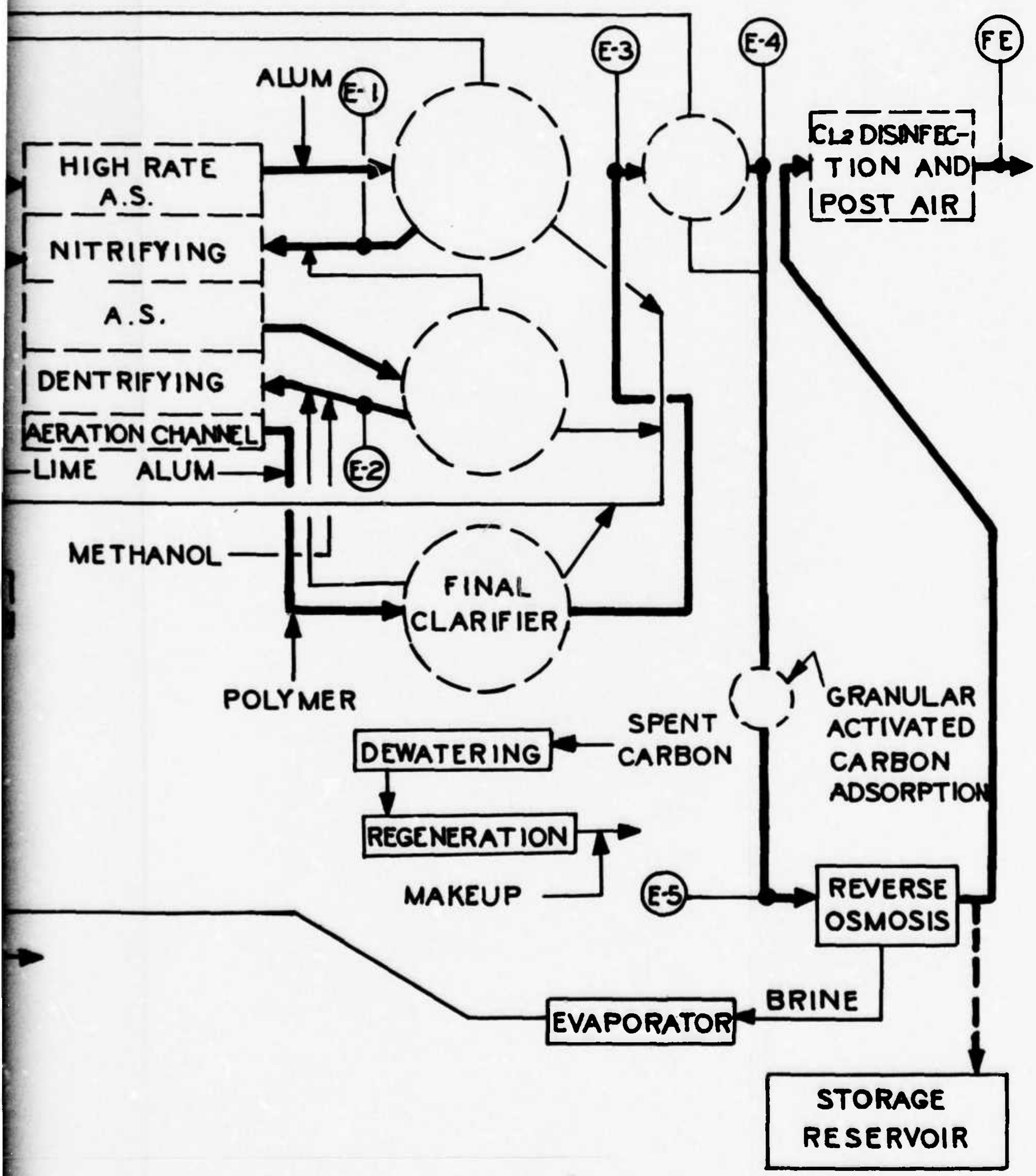


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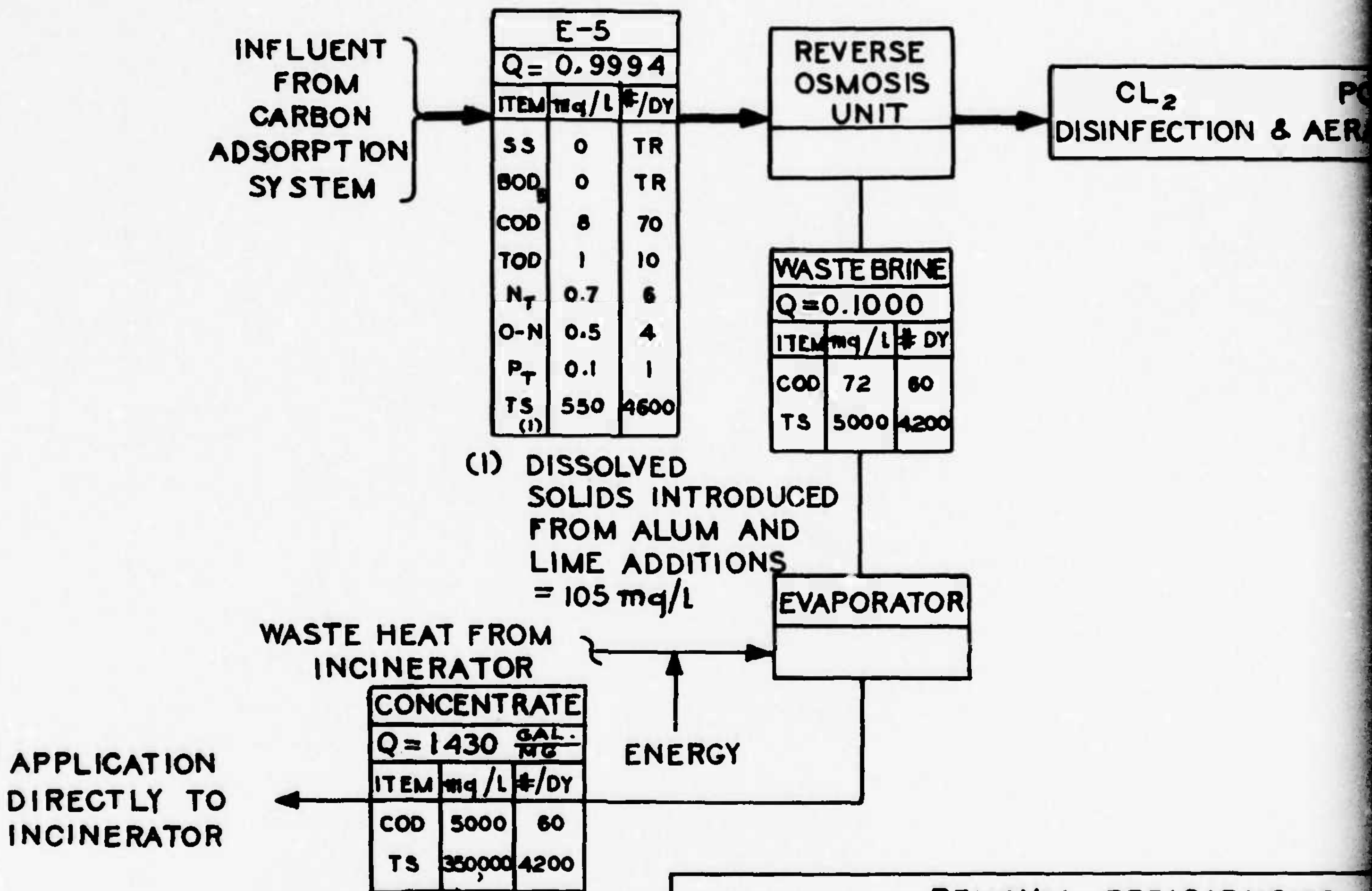
FIGURE 9

BASIC BIOLOGICAL TREATMENT SYSTEM UPGRADED FOR ULTIMATE REUSE APPLICATIONS

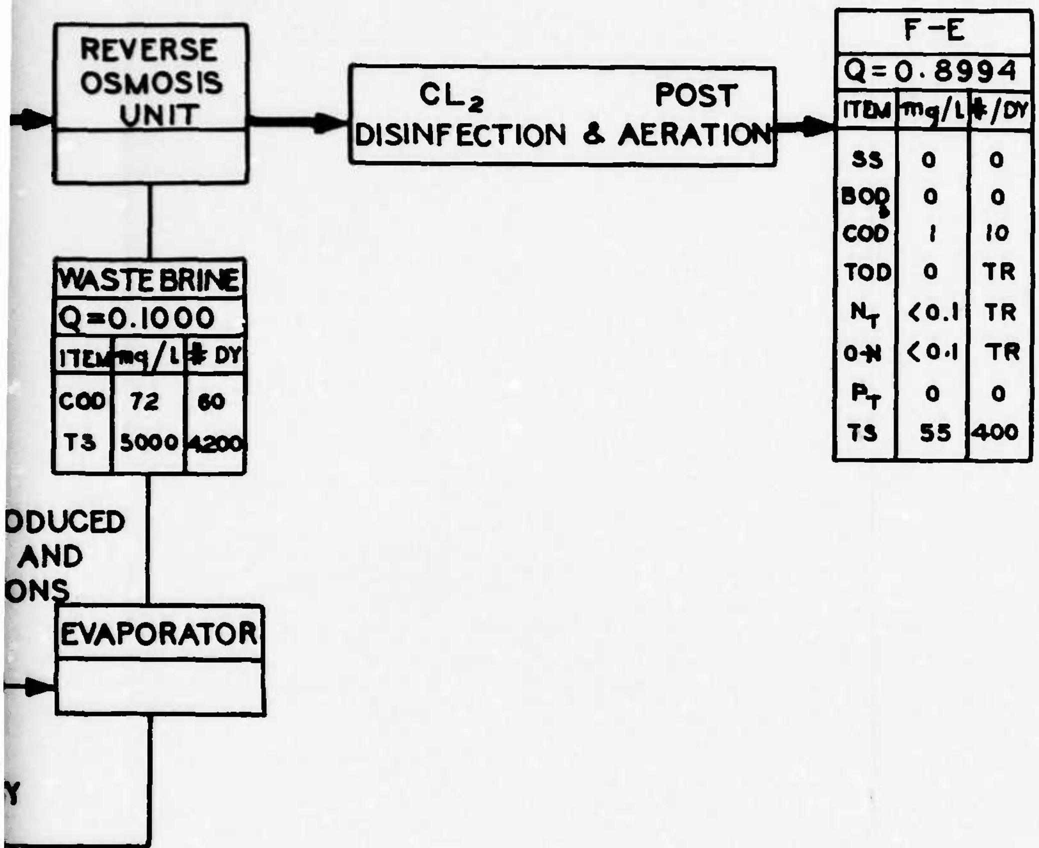


REMOVAL EFFICIENCIES

ITEM	PE	E-1	E-2	E-3	E-4
SS	48	86	88	97	99
BOD_5	11	88	97	98	99
COD	8	81	89	93	94
TOD	2	67	94	96	98
N	-22	16	16	90	91
P	-7	79	79	96	99
TS *	8	24	23	26	27

* INITIAL TS ASSUMED AT 785 mg/L

/

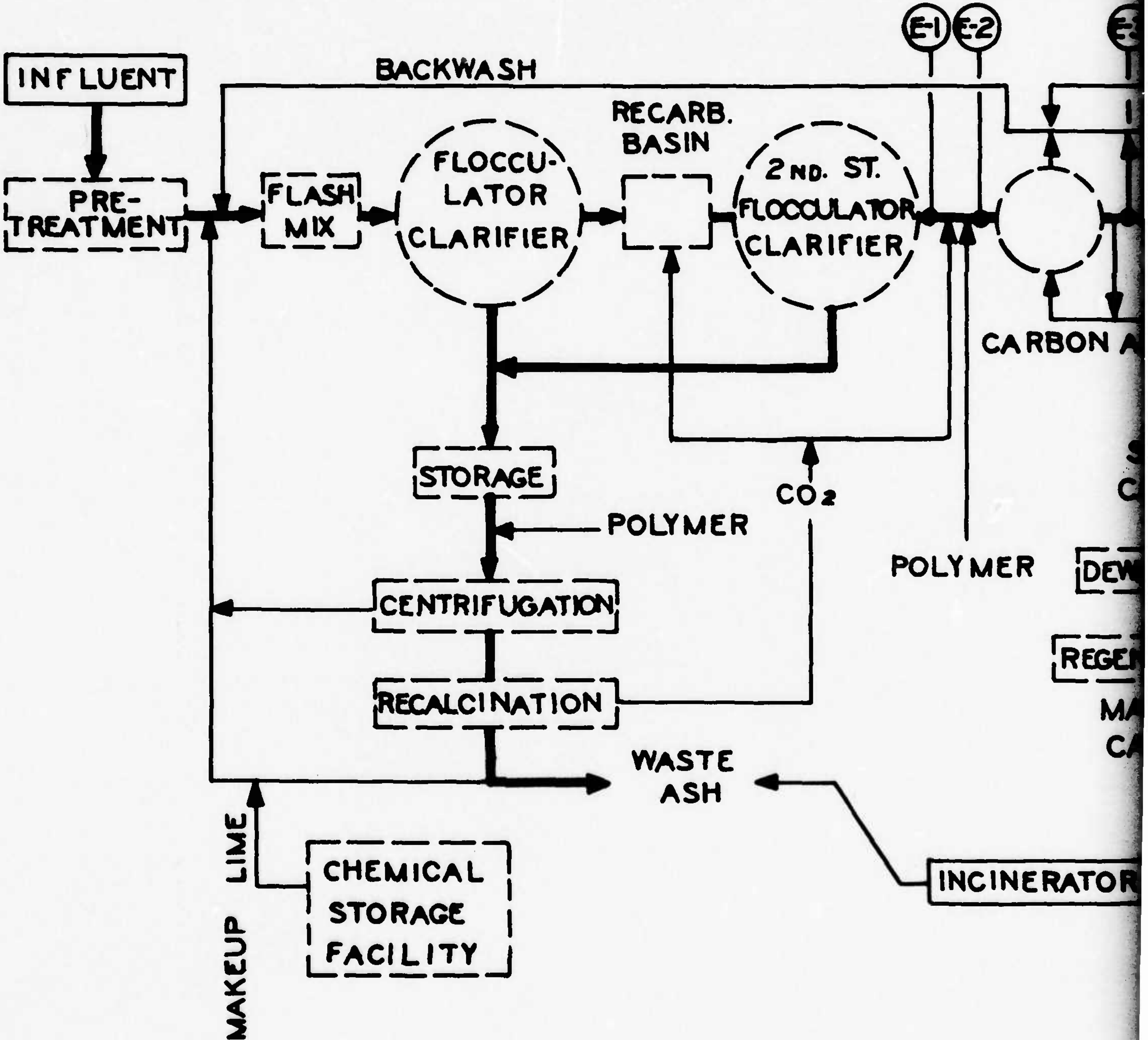


REMOVAL EFFICIENCIES							
EM	PE	E-1	E-2	E-3	E-4	E-5	FE
S	48	86	88	97	99	100	100
D$_5$	11	88	97	98	99	100	100
D	8	81	89	93	94	98	99+
D	2	67	94	96	98	99+	99+
	-22	16	16	90	91	97	99+
	-7	79	79	96	99	99+	100
S *	8	24	23	26	27	30	94

INITIAL TS ASSUMED AT 785 mg/L

2

FIGURE 9A
BASIC BIOLOGICAL TREATMENT SYSTEM UPGRADED FOR ULTIMATE REUSE APPLICATIONS: PROCESS PERFORMANCE



HAVENS AND EMERSON, LIMITED

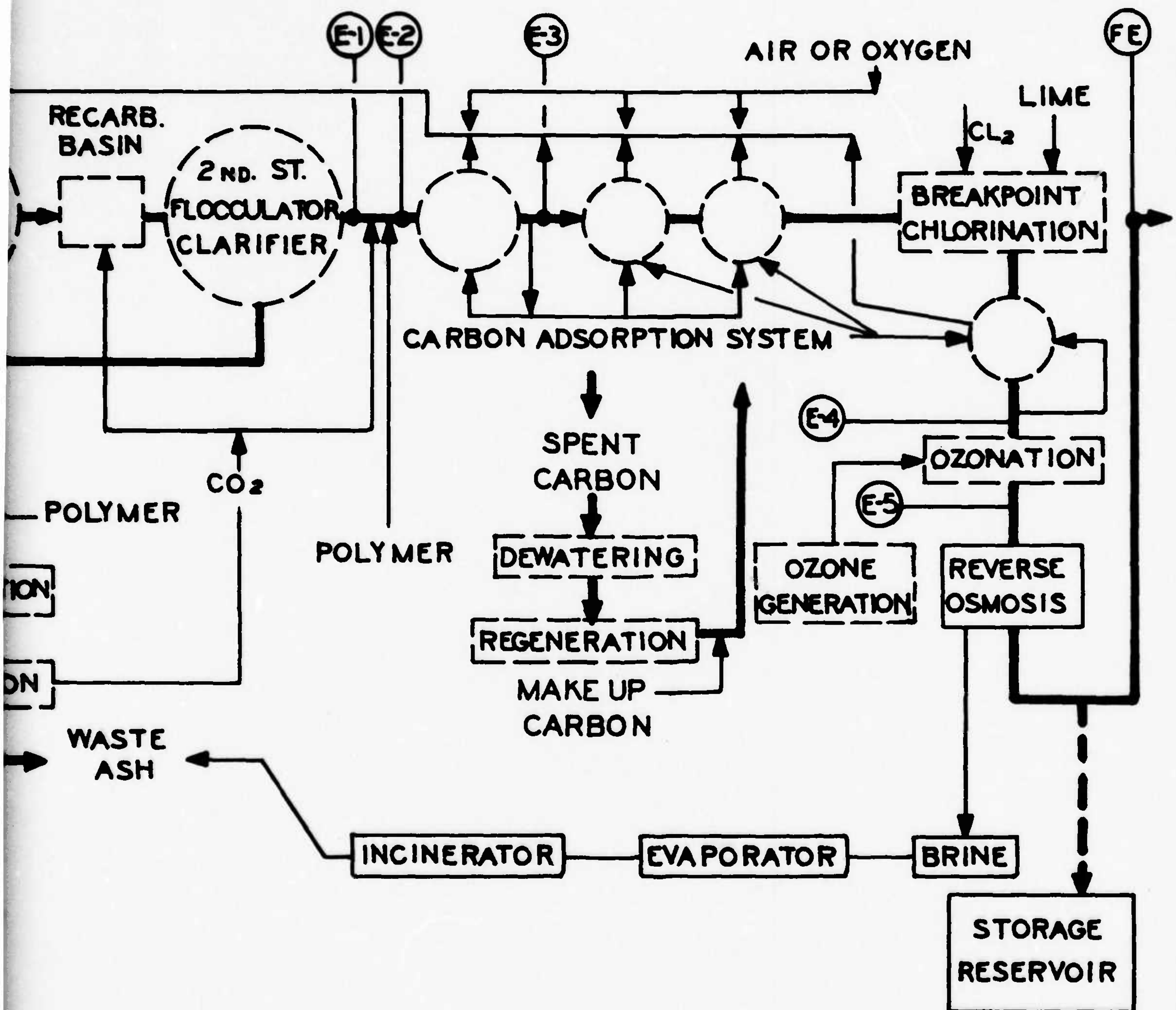


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FIGURE 10

BASIC PHYSICAL-CHEMICAL TREATMENT SYSTEM UPGRADED FOR ULTIMATE REUS APPLICATIONS

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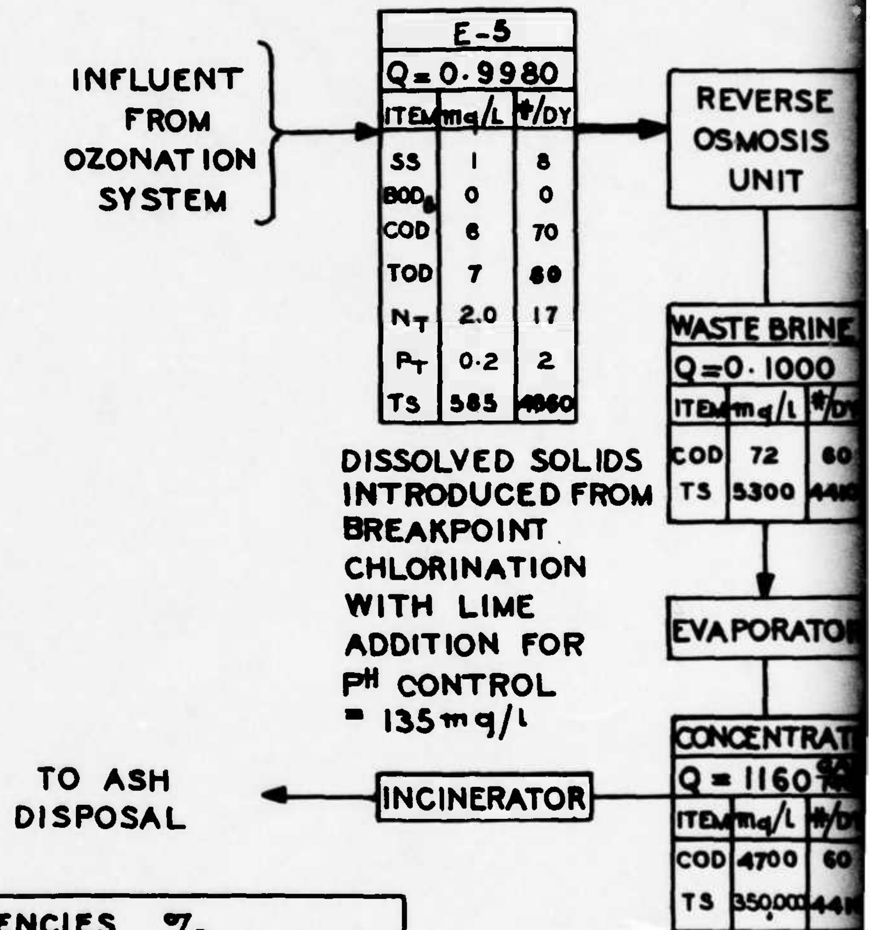

REMOVAL EFFICIENCIES %						
ITEM	E-1	E-2	E-3	E-4	E-5	FE
SS	89	95	99	99	99+	100
BOD_5	74	74	76	97	100	100
COD	51	51	52	96	98	99+
TOD	61	61	62	96	98	99+
N_T	28	28	29	91	91	99+
P_T	90	90	95	98	98	100
TS*	22	22	23	21	21	92

* INITIAL TS ASSUMED AT 785 mg/l

HAVENS AND EMERSON, LIMITED

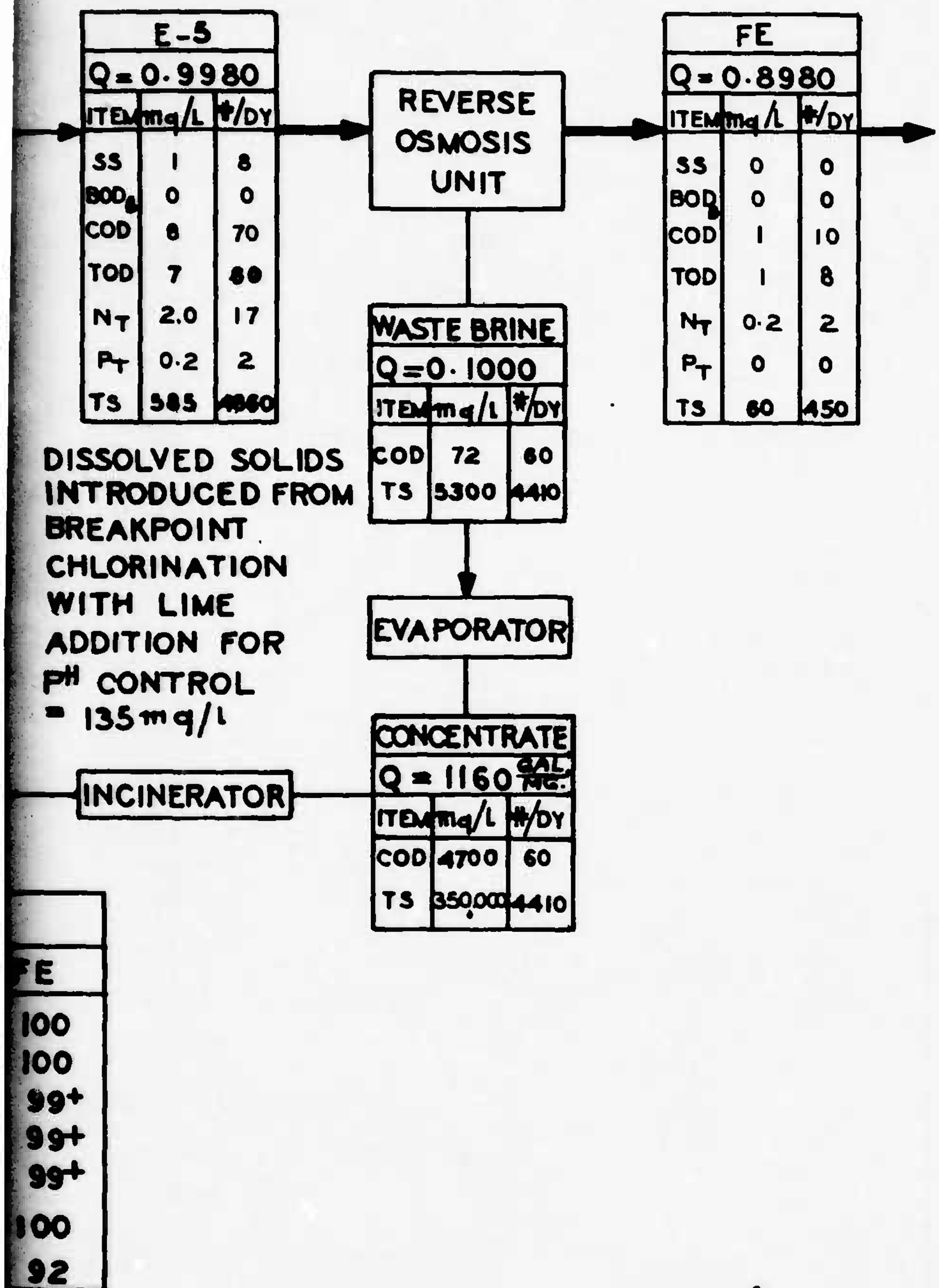

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FIGURE 10A

BASIC PHYSICAL-CHEMICAL TREATMENT SYSTEM UPGRADED FOR ULTIMATE REUSE APPLICATIONS: PROCESS PERFORMANCE

2. DESIGN CRITERIA

Design criteria were established for various basic elements of a wastewater management program for use in the preliminary design development of the alternative plans.

2.1 DEFINITION OF FLOW TERMS

A definition of flow related terms is provided followed by a description of the design criteria.

Dry weather flow (DWF) is defined as the flow received at the plant on days when no precipitation occurs, and when antecedent runoff is not affecting flow materially.

Average Daily Flow (ADF) is defined as the total annual flow received divided by 365 days. ADF includes ground water infiltration and certain amounts of storm water inflitration and is the value normally used in the sanitary engineering profession as the average design flow for treatment units.

Maximum Flow (MF) is defined as the peak hourly flow rate accepted for full treatment.

Maximum Daily Flow (MDF) is defined as the highest 24 hour flow received during a year.

Maximum Hourly Flow (MHF) is the flow received in the maximum hour in a day and represents the peak diurnal flow.

The above values are related as follows:

ADF = 1.1 to 1.2 x DWF	Use: 1.15 x DWF
MDF = 1.4 to 1.7 x ADF	Use: 1.50 x ADF
MF = 2.5 ADF = 2.9 DWF	Use: 3.00 x DWF
MF =1.35 x MDF = 1.35 x 1.6 x ADF	Use: 2.50 x ADF
MHF = 1.2 to 1.5 ADF	Use: 1.35 x ADF

2.2 MUNICIPAL TREATMENT PLANTS

The design criteria for the conventional activated sludge plant, the advanced biological treatment plant, and the physical chemical plant are

discussed in detail in the previous section of this report. The conventional activated sludge plant and the advanced biological plants were considered to have a useful life of 35 years. The physical chemical treatment plants were considered to have a useful life of 25 years.

In calculating these useful lifes, the following rational using a weighted average was employed:

ADVANCED BIOLOGICAL SYSTEM:

Component	Useful Life	Percent of Plant Cost
pretreatment and primary unit	45 years	33.3
secondary, denitrifications and nitrification unit	40 years	33.3
tertiary units	20 years	33.3
weighted average	35 years	

PHYSICAL CHEMICAL SYSTEM:

Component	Useful Life	Percent of Plant Cost
phosphorous removal, coagulation sedimentation	40 years	25
carbon adsorption, breakpoint chlorination ozonation	20 years	75
weighted average	25 years	

2.3 LOADING RATIOS

In a treatment process, the various units are designed for both a hydraulic and pollutant mass loading greater than that of the average daily flow. Likewise, components of the unit process itself are designed with different loading factors. Generally, those unit processes such as sedimentation and physical separation are more dependant upon hydraulic loading whereas the biological-chemical reactors are more dependant upon pollutant mass loading.

The following statements define the loading ratios for the advanced

biological systems. For a physical-chemical system, the carbon absorption ration would be 1.5 times the average daily flow.

Preliminary, primary and secondary treatment:

Design criteria will be based on ADF with higher loadings permitted at MF. We therefore expect variations in effluent quality in the range of 20-30 mg/1 BOD and SS, through the secondary treatment stage.

Mixed Media Filtration:

Secondary treatment has a definite buffering effect, and the process effectiveness is related to solids loading as well as flow rate.

Design Rates: ADF = 2.0 gpm/s.f.

MF = 5 gpm/s.f.

Biological Nitrification and Dentrifications:

These processes are nitrogen mass and temperature dependent and are partly effected by detention time. Use conservative design rates:

Nitrification: ADF = 6 hours detention MF = 4 hours
Denitrification: ADF = 3 hours detention MF = 2 hours
Carbon Adsorption: MF = 1.0 x ADF

Carbon adsorption when it follows filtration (as assumed herein) is primarily dependent upon dissolved organic concentration. Flow variations when following biological stabilization have minor effect. Design based on 3-4 gpm/s.f. 15 minute contact at MF.

Reverse Osmosis:

The reverse osmosis process is dependent upon flux rate, but the process is capable of exceeding the standards established on some

constituents. For study purposes, a constant flow rate can be assumed at ADF, with maximum flow increments by-passed in a split flow process.

2.4 PUMP STATIONS

Sewage pumping stations must be evaluated based upon average flow conditions. The pumping station, however, should be sized greater than the average flow to account for variations in sewage flow and standby capacity for mechanical failures. For an average flow of 1 mgd (approximately 10,000 people) or less total standby has been provided. For an average flow of greater than 1 mgd, 1/2 standby has been provided. In all cases firm capacity is provided for peak flows with the largest unit out of service. The need for greater standby capacity in the smaller pump stations is due to the greater variation in average to peak flows. Cost estimates include provision of diesel-electric standby power generation.

Sewage pumping stations are generally designed for a 20 year design period.

The pumping station power costs have been based on a pump efficiency of 75%, the appropriate pumping head, and a power cost of 1.21¢ per KWH.

2.5 GRAVITY SEWERS

In determination of sewer slopes, profiles were taken from U.S.G.S. 1:24000; topographic maps. Pipe sizes were based on these slopes and the resulting discharges from population and flow projections. A peaking factor was applied to the average discharge. The peaking factor used was curve A in figure 4 of the American Society of Civil Engineers manual number 37. This curve has been verified in the Northeast Ohio area by previous studies done by Havens and Emerson. The minimum allowable velocity for 1970

minimum flows was 1.5 feet per second. The maximum allowable velocity for peak flows was 10 feet per second. The desired velocity was 3-6 feet per second. The minimum and maximum trench depths were 10 feet and 30 feet, respectively. For depths greater than 30 feet, tunneling was assumed. Mannings' roughness coefficient of 0.015 was selected for concrete pipe flowing full.

The gravity sewers were designed based on 2020 design flows with a useful life of 50 years.

2.6 FORCE MAINS

Force mains were designed for maintaining velocities between 4 and 6 feet per second. The discharges were based on population and flow projections. Force mains have a minimum cover of 5 feet except for any required tunneling. Cast iron pipe was considered for lines less than 24-inches in diameter and reinforced concrete pressure pipe was considered for lines 24-inches and larger in diameter. The roughness coefficient varies depending upon the character of the liquid (sludge or sewage) pumped and the pipe material. A minimum pipe diameter of 8-inches was established.

Force mains were designed based on 2020 design flow with a useful life of 50 years.

2.7 OUTFALL SEWERS

Outfall sewers were based on maintaining velocities of 2 to 4 feet per second. The outlet location was placed in at least 15 feet of water. Reinforced concrete pipe was used with a minimum diameter of 18 inches.

Outfall sewers were designed for 2020 design flows.

3. UNIT COSTS

Table 3 lists the wastewater treatment methods for which capital construction costs and operation and maintenance costs have been developed. These costs were developed for use in preparation of cost estimates for the alternative plans with an ENR construction index of 1740. Capital costs reflect the construction cost with no contingency allowance, except for the gravity sewer and force main cost which include 25% for contingencies. For the estimates construction costs without contingencies were used.

The capital costs are expressed in either Dollars per MGD of plant size (MGD) or Dollars per Dry Ton per Day of sludge facility size versus plant size (MGD) or sludge facility size (Dry Tons per Day), respectively. The operation and maintenance costs are expressed in either Dollars per MG of wastewater treated or Dollars per Dry Ton of sludge treated plant size (MGD) or sludge facility size (Dry Tons per Day), respectively. Plant size (MGD) is based on average daily flow. The reference numbers follow the process being discussed with the references listed in appendix A.

TABLE 3

WASTEWATER TREATMENT UNIT COSTS
FIGURE IDENTIFICATION

	Capital Cost	O&M Cost
Activated Sludge with Primary	11	11A
Phosphorus Removal	12	12A
Chlorination	13	13A
Ozonation	14	14A
Nitrification	15	15A
Denitrification	16	16A
Coagulation and Sedimentation	17	17A
Microstrainers	18	18A
Mixed Media Filters	19	19A
Carbon Adsorption	20	20A
Breakpoint Chlorination	21	21A
Sludge Thickener	22	-
Sludge Digestion	23	23A
Heat Treatment	24	24A
Vacuum Filter	25	25A
Incineration	26	26A
Pump Station	27	27A
Gravity Sewer - Urban	28	-
Gravity Sewer - Rural	29	-
Force Main	30	-
Tunnel	31	-
Deep Tunnel	32	-

Following is a brief description of these methods to identify assumed design parameters and cost data references.

Activated sludge with Primary - Figures 11 and 11A represent the total capital cost and operation and maintenance cost for a conventional activated sludge plant including preliminary treatment, primary settling tanks, aeration tanks, (4.5 to 6 hours contact time), final settling tanks, blower building, and administration and laboratory facilities. These curves do not reflect any costs for sludge handling. Ref. * 1,4,5,8,19

Phosphorus Removal - Figures 12 and 12A represent the total capital

*For cost data sources see References, Appendix A.

cost and operation and maintenance cost for phosphorus removal accomplished through metal salt addition to the aerator effluent. Chemical feed facilities and housing are the only required capital expenditures. Ref. 4,15

Chlorination - Figures 13 and 13A represent the total capital cost and operation and maintenance cost for chlorination of plant effluent. A 30 minute contact time at average flow with a chlorine residual of 0.5 mg/1 was the basic design criteria. Ref. 1,8,19,17

Ozonation - Figures 14 and 14A represent the total capital cost and operation and maintenance cost for ozonation. Costs have been computed for various dosage concentrations to illustrate the cost fluctuations. It was assumed that 5 mg/1 was adequate for disinfection and 20-30 mg/1 was adequate for COD removal. Ref. 9,11

Nitrification - Figures 15 and 15A represent the total capital cost and operation and maintenance cost for nitrification. This is accomplished through modification of the conventional activated sludge plant with a 1/3 - 2/3 volumetric split of the existing aerator which results in a nitrifying contact time of 3 to 4 hours. A new final clarifier is required to allow the complete separation of the two distinct biological cultures. The capital cost therefore assumes addition to a conventional activated sludge plant. Ref. 10,14

Denitrification - Figures 16 and 16A represent the capital cost and operation and maintenance cost for denitrification. This includes a denitrification reactor, (3 hours detention) an aerated channel, and an additional final clarifier. Ref. 10

Coagulation and Sedimentation - Figures 17 and 17A represent the capital cost and operation and maintenance cost for coagulation and sedimentation after lime addition. This is a two stage treatment consisting of a flash

mix chamber, and a flocculator-clarifier basin followed by recarbonation and a second stage flocculator-clarifier. The lime recovery and reuse system includes lime mud dewatering, a recalcination reactor and slaker. Ref. 1,4,15,19

Microstrainers - Figures 18 and 18A represent the capital cost and operation and maintenance cost for microstraining of secondary effluent. Maximum hydraulic loadings were assumed between 600-800 gal/sq.ft./hr., with a Mark I (35 micron fabric) screen. Ref. 1,4,16

Mixed Media Filters - Figures 19 and 19A represent the capital cost and operation and maintenance cost for mixed media filters. Filter loading rates are based on a hydraulic loading of 2 gpm/sq.ft. for average daily flow. Ref. 1,4,16,3,18,19

Carbon Adsorption - Figures 20 and 20A represent the capital cost and operation and maintenance cost for carbon adsorption following filtration. The design is based on 3-4 gpm/sq.ft. and a contact time of 15 minutes for average daily flow. Included in this cost is regeneration of the spent carbon in a high temperature reactor. Ref. 1,4,12,18

Breakpoint Chlorination - Figures 21 and 21A represent the total capital cost and operation and maintenance cost for breakpoint chlorination. This cost includes a small contact chamber and facilities for the chemical feed equipment. For the physical chemical plant (Level 2) the dosage is 103 mg/l. For the stormwater treatment plant (Level 2) the dosage is 52 mg/l.

Sludge Thickeners - Figure 22 represents the total capital cost for gravity thickening of waste activated sludge. The design assumes a loading of four pounds/sq.ft./day. Ref. 1

Sludge Digestion - Figures 23 and 23A represent the total capital cost and operation and maintenance cost for sludge digester. The design assumes a 30 day detention period with a percent feed solids of 3.6. Ref. 1,5,18,12

Heat Treatment - Figures 24 and 24A represent the total capital cost and operation and maintenance cost for heat treatment. This design assumes a low pressure oxidation unit with allowances made for shift differential for various plant sizes. One shift for plants less than 10 mgd, two shifts for plants between 10-30 mgd, and three shifts for plants greater than 30 mgd. Ref. 6,2

Vacuum Filter - Figures 25 and 25A represent the total capital cost and operation and maintenance cost for vacuum filters. A loading rate of 4 lbs./sq.ft./hr. was assumed for digested sludge and 10 lbs./sq.ft/hr. for heat treated sludge. Allowances were also made for shift differentials for the same plant sizes as for heat treatment. Ref. 1,5,18,2

Incineration - Figures 26 and 26A represent the total capital cost and operation and maintenance cost for incinerating sludge filter cake. Allowances were also made for shift differentials for various plant size. Ref. 5,2

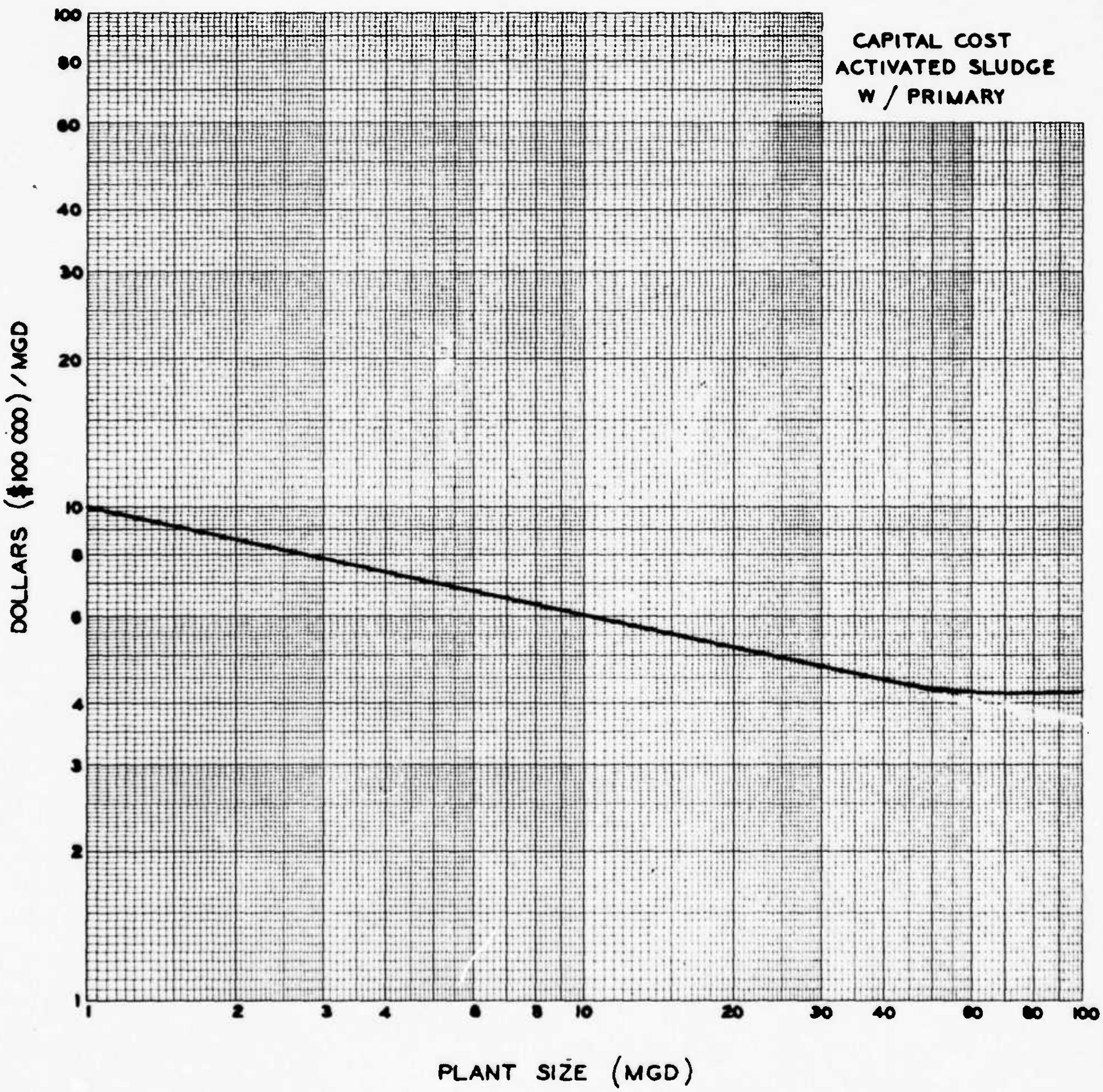
Pump Station - Figures 27 and 27A represent the total capital cost and operation and maintenance cost for pump station. Operation and maintenance costs are shown for total dynamic heads of 50, 100, and 200 feet. Ref. 4,5

Gravity Sewer - Urban and Rural - Figures 28 and 29 represent the total capital cost for gravity sewers for urban and rural areas, respectively. Each figure shows two curves to allow for different depths of cover. This cost includes sewer cost, excavation, backfill, pavement replacement and 25% for contingencies. The urban cost allows for utility protections, off site storage of excavated materials, and tighter working conditions.

Force Main - Figure 30 represents the capital cost for force mains. This cost includes pipe cost, excavation, backfill, allowances for pavement replacement, and 25% for contingencies.

Tunnel - Figure 31 represents the total capital cost for tunnel construction. This cost was used for river crossings, railroad crossings, and in certain instances in heavily urbanized areas.

Deep Tunnel - Figure 32 represents the total capital cost for deep tunnel construction in shale. The tunnel will be drilled using a shield type mining machine and lined with a minimum of 18 inches of reinforced concrete. Ref. 20



CAPITAL COST
ACTIVATED SLUDGE
W / PRIMARY
DOLLARS ($100 000) / MGD
PLANT SIZE (MGD)

Figure No. 11

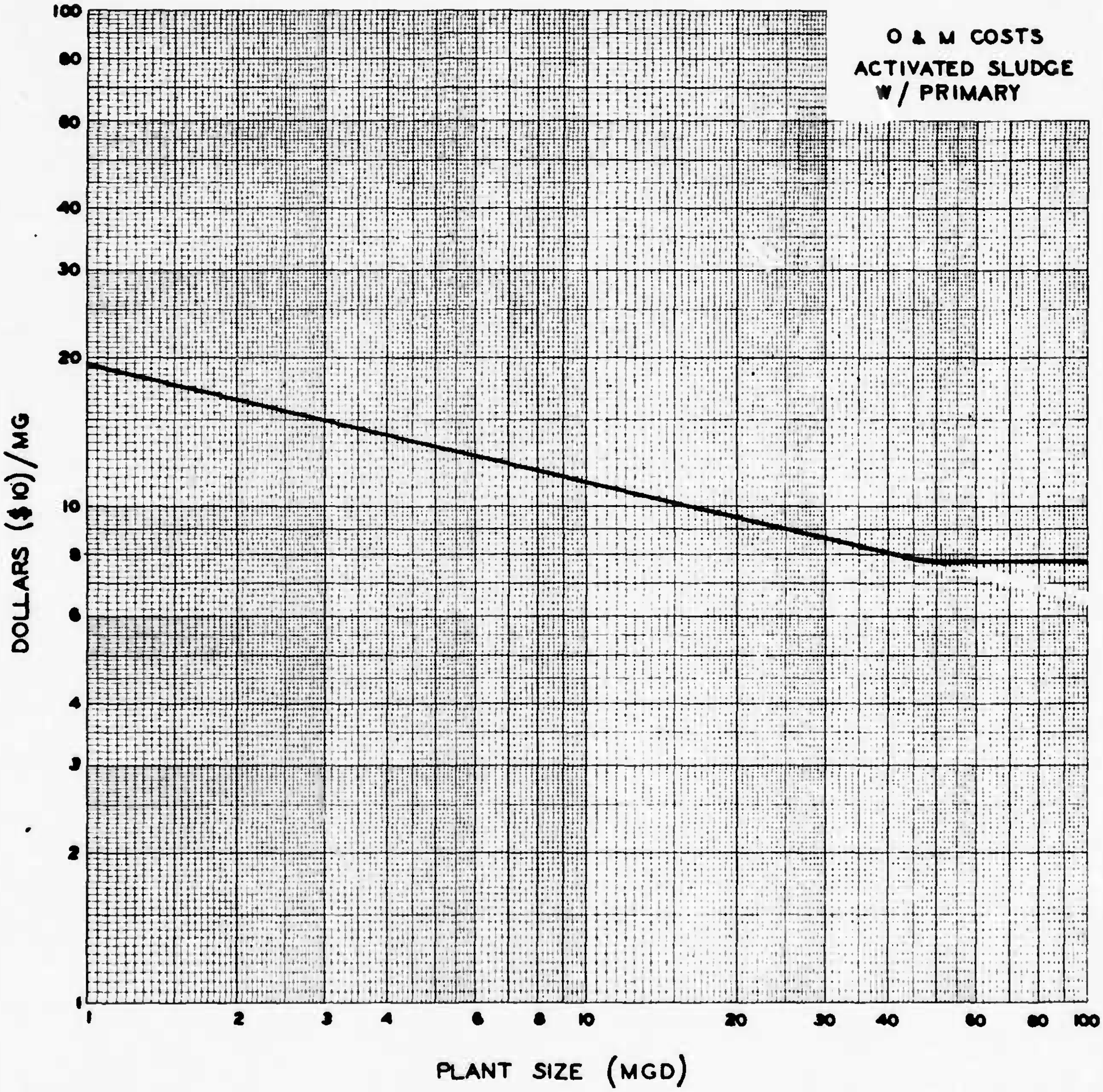


Figure No. 11_A

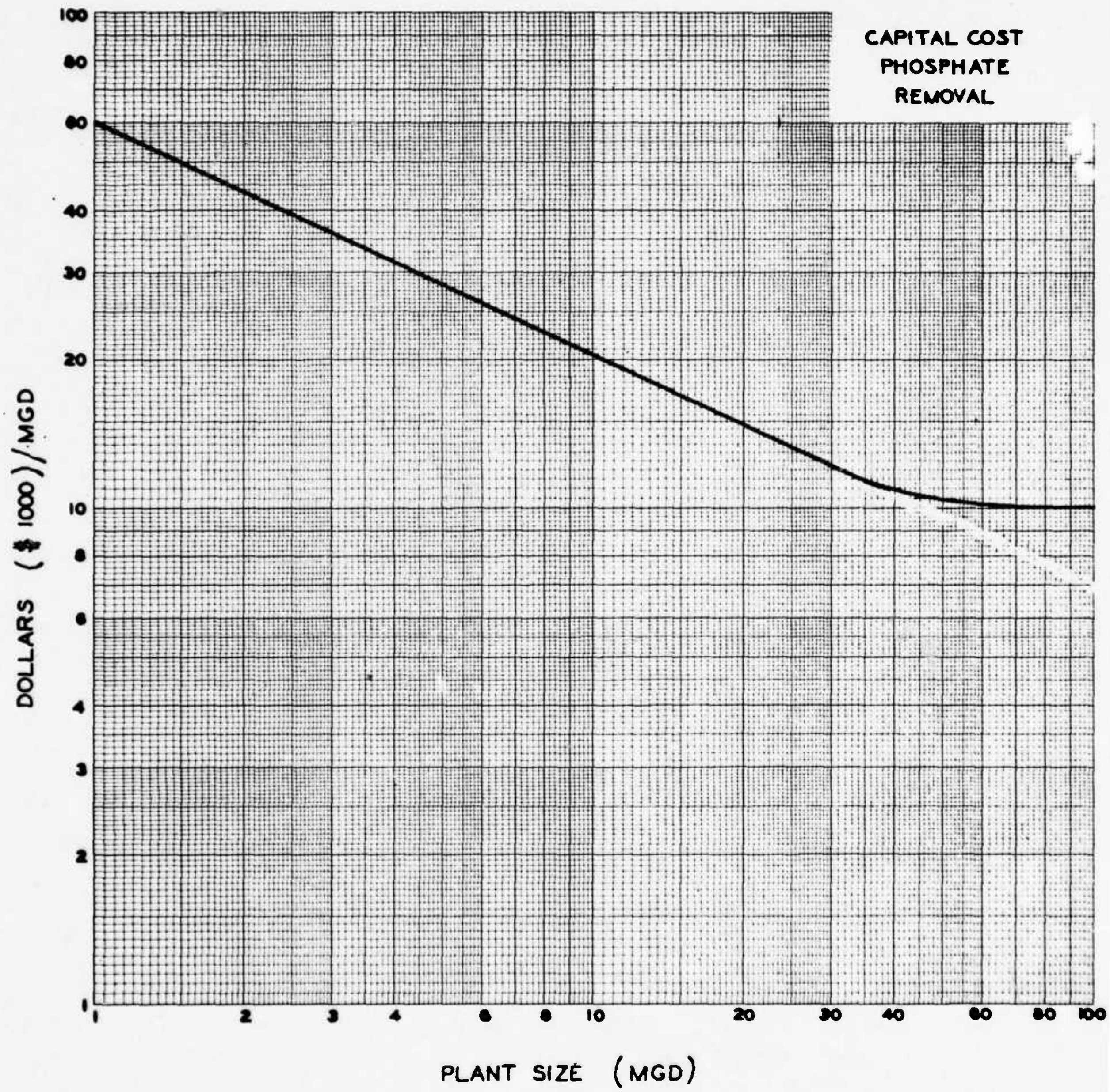

CAPITAL COST
PHOSPHATE
REMOVAL
DOLLARS ($ 1000)/MGD
PLANT SIZE (MGD)
100
80
60
40
30
20
10
8
6
4
3
2
1
1
2
3
4
6
8
10
20
30
40
60
80
100

Figure No. 12

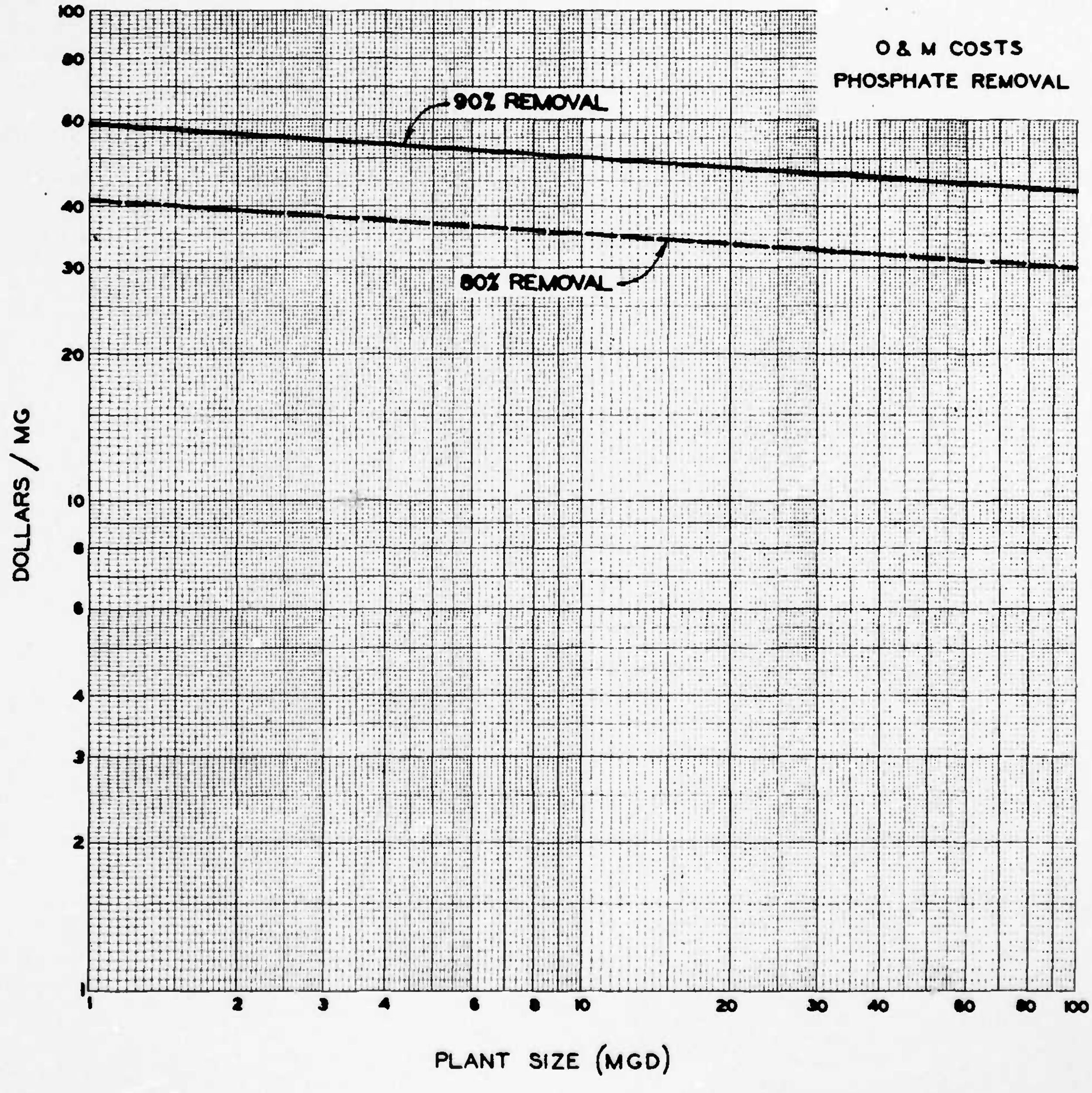


Figure No. 12A

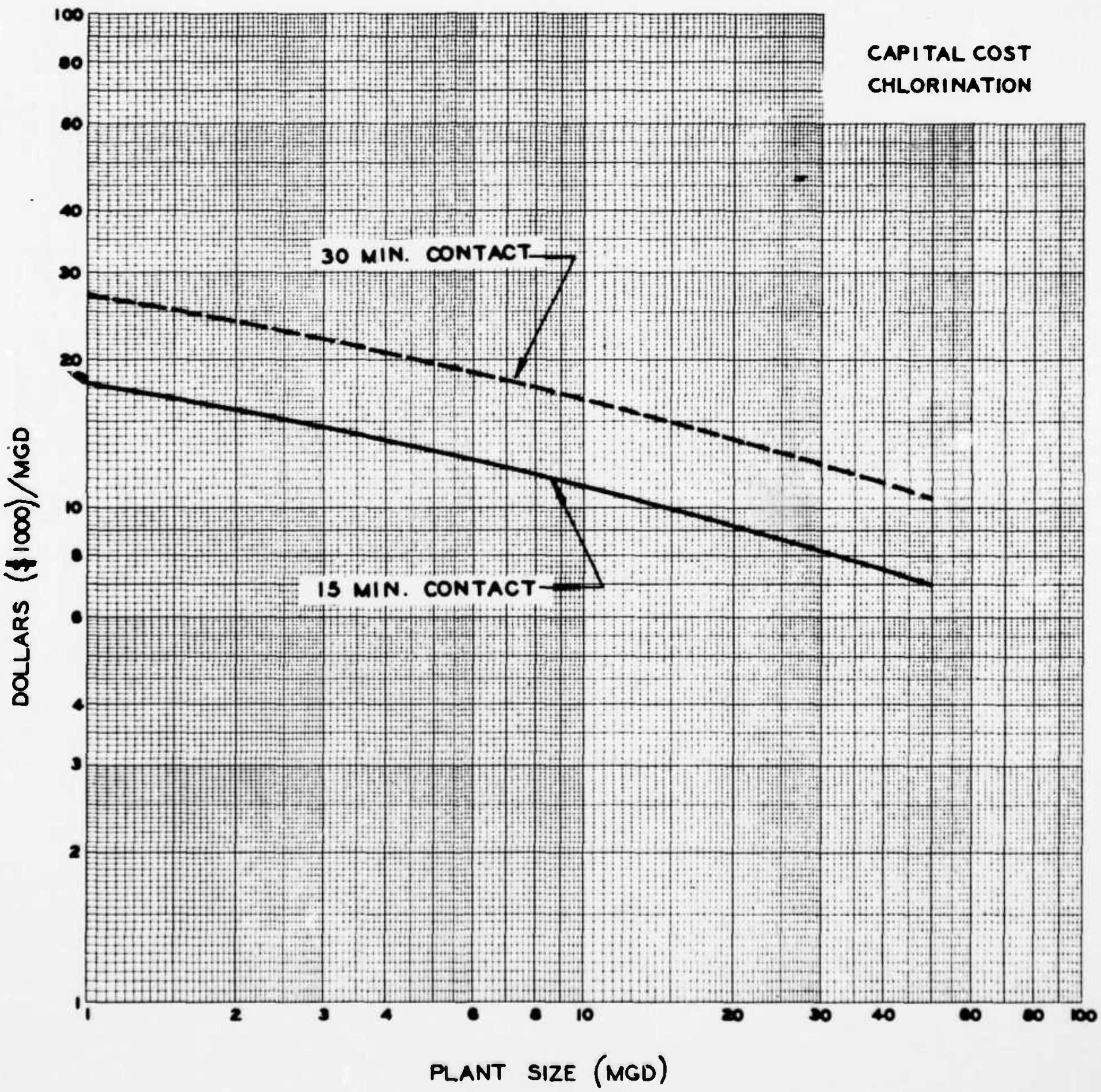

CAPITAL COST
CHLORINATION
30 MIN. CONTACT
15 MIN. CONTACT
DOLLARS ($1000)/MGD
PLANT SIZE (MGD)
100
80
60
40
30
20
10
8
6
4
3
2
1
1
2
3
4
6
8
10
20
30
40
60
80
100

Figure No. 13

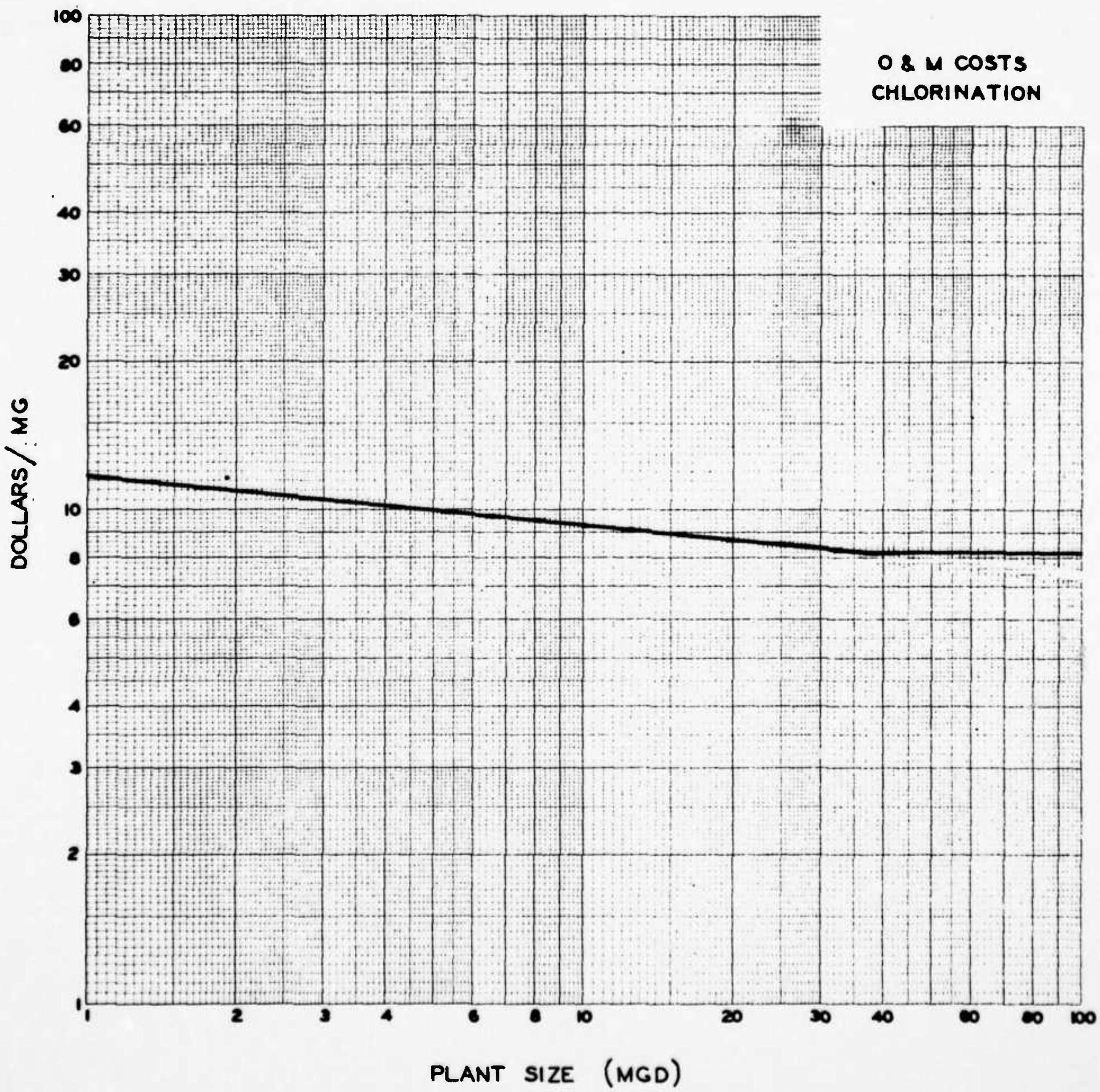
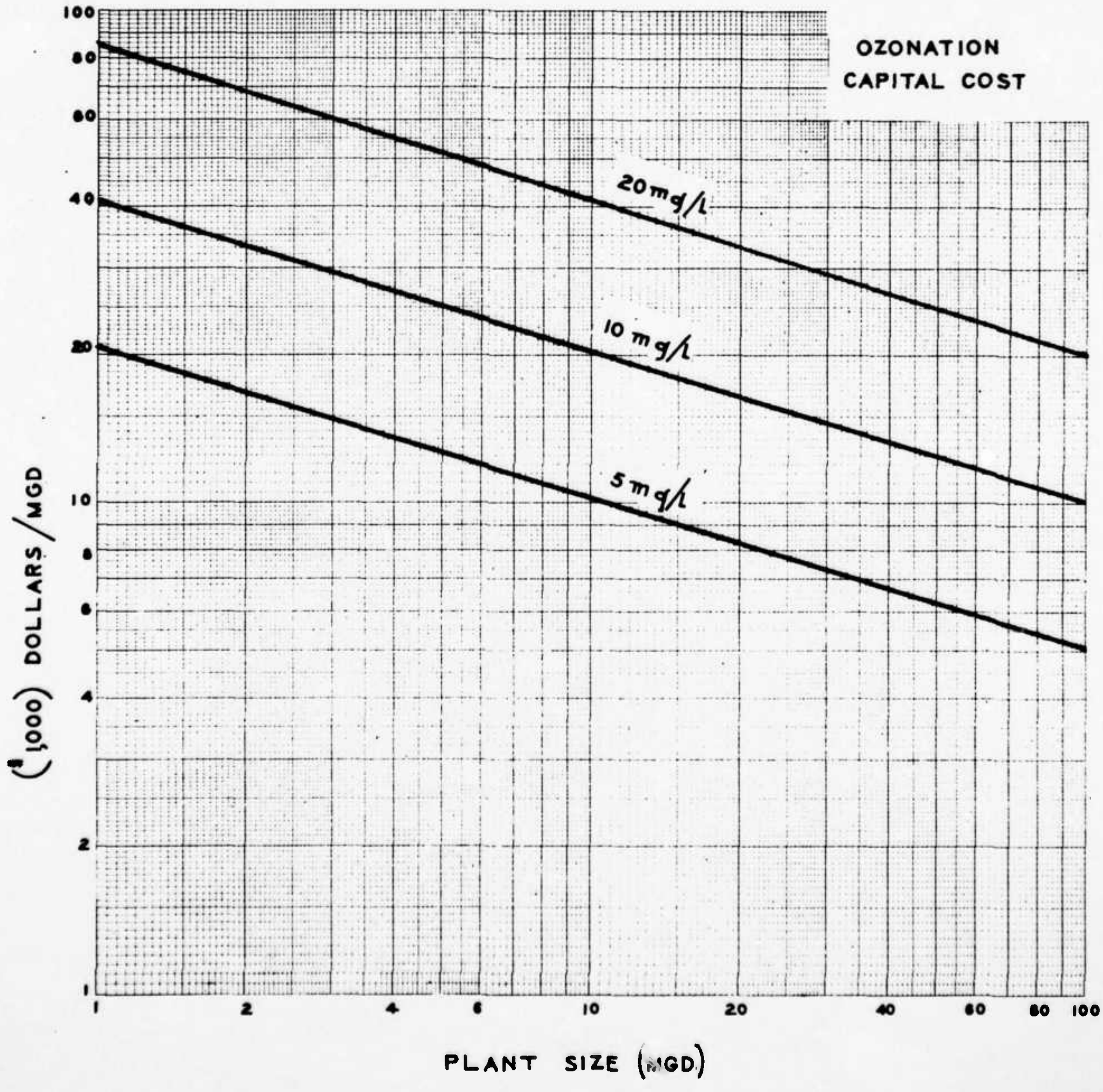


Figure No. 13A



OZONATION
CAPITAL COST
20 mg/l
10 mg/l
5 mg/l
($1,000) DOLLARS/MGD
100
80
60
40
20
10
8
6
4
2
1
1
2
4
6
10
20
40
60
80
100
PLANT SIZE (MGD)

Figure No. 14

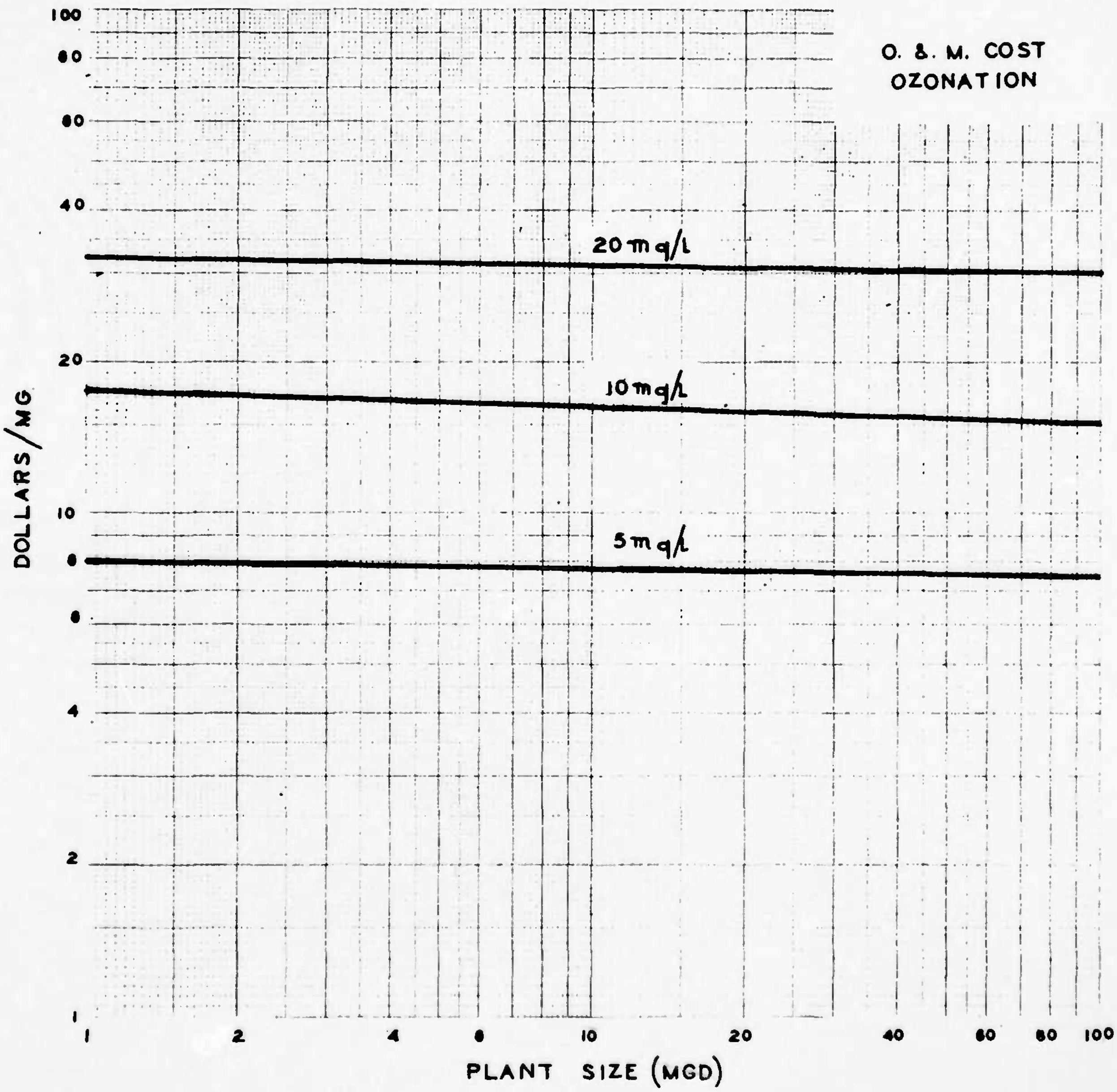


Figure No. 14A

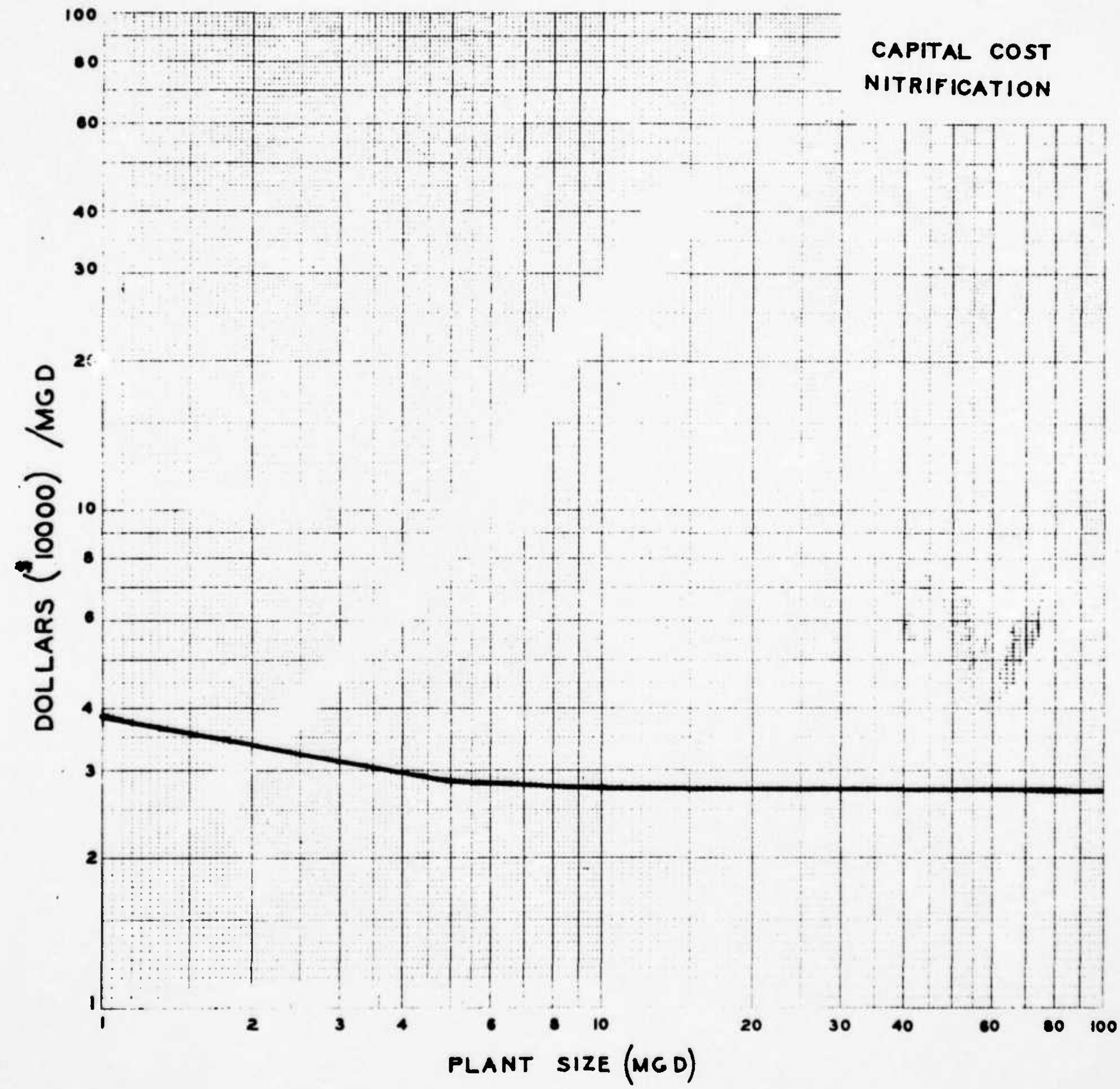

CAPITAL COST
NITRIFICATION
DOLLARS ($10000) /MGD
PLANT SIZE (MGD)
100
80
60
40
30
20
10
8
6
4
3
2
1
1
2
3
4
6
8
10
20
30
40
60
80
100

Figure No. 15

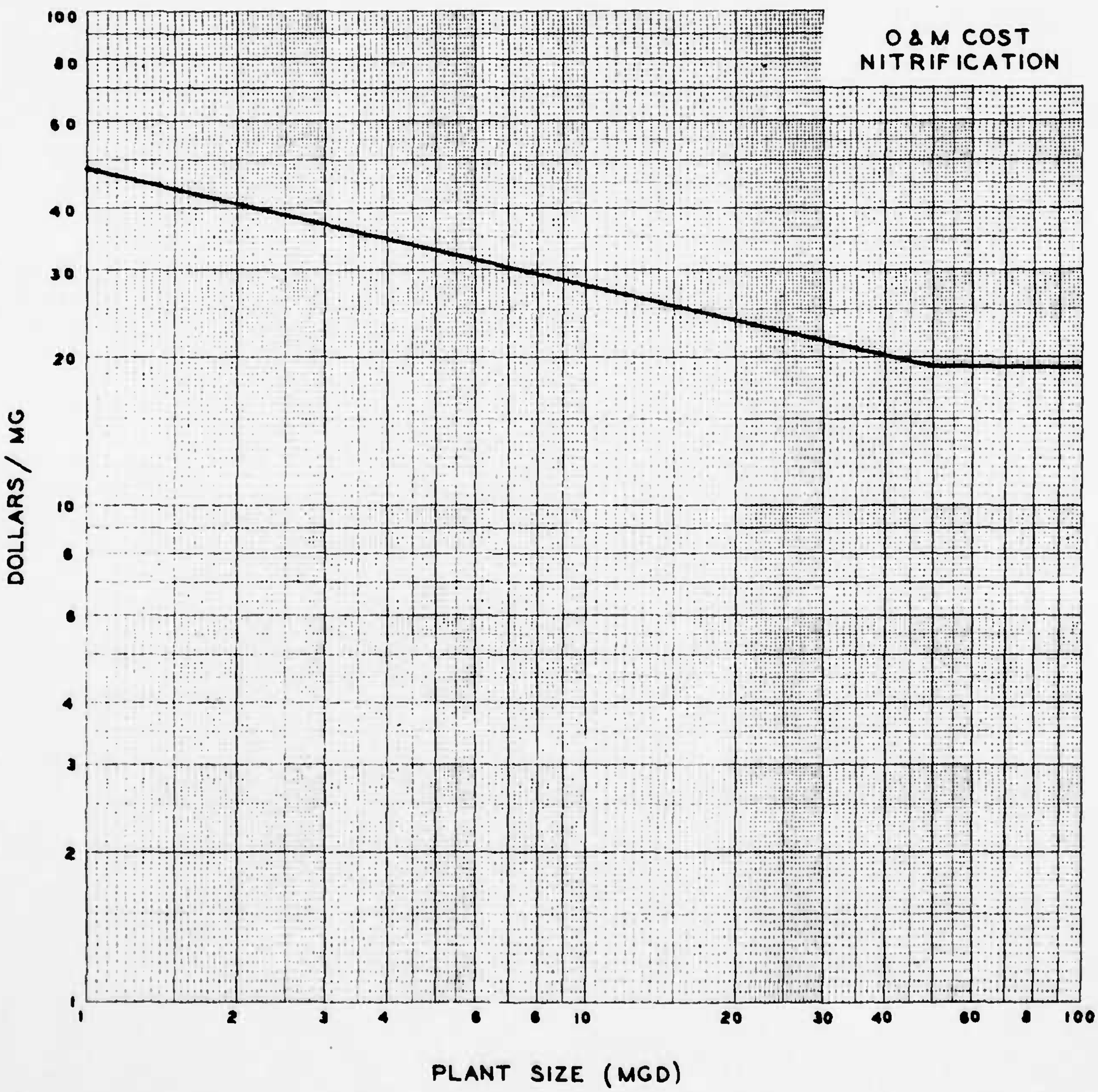


Figure No. 15A

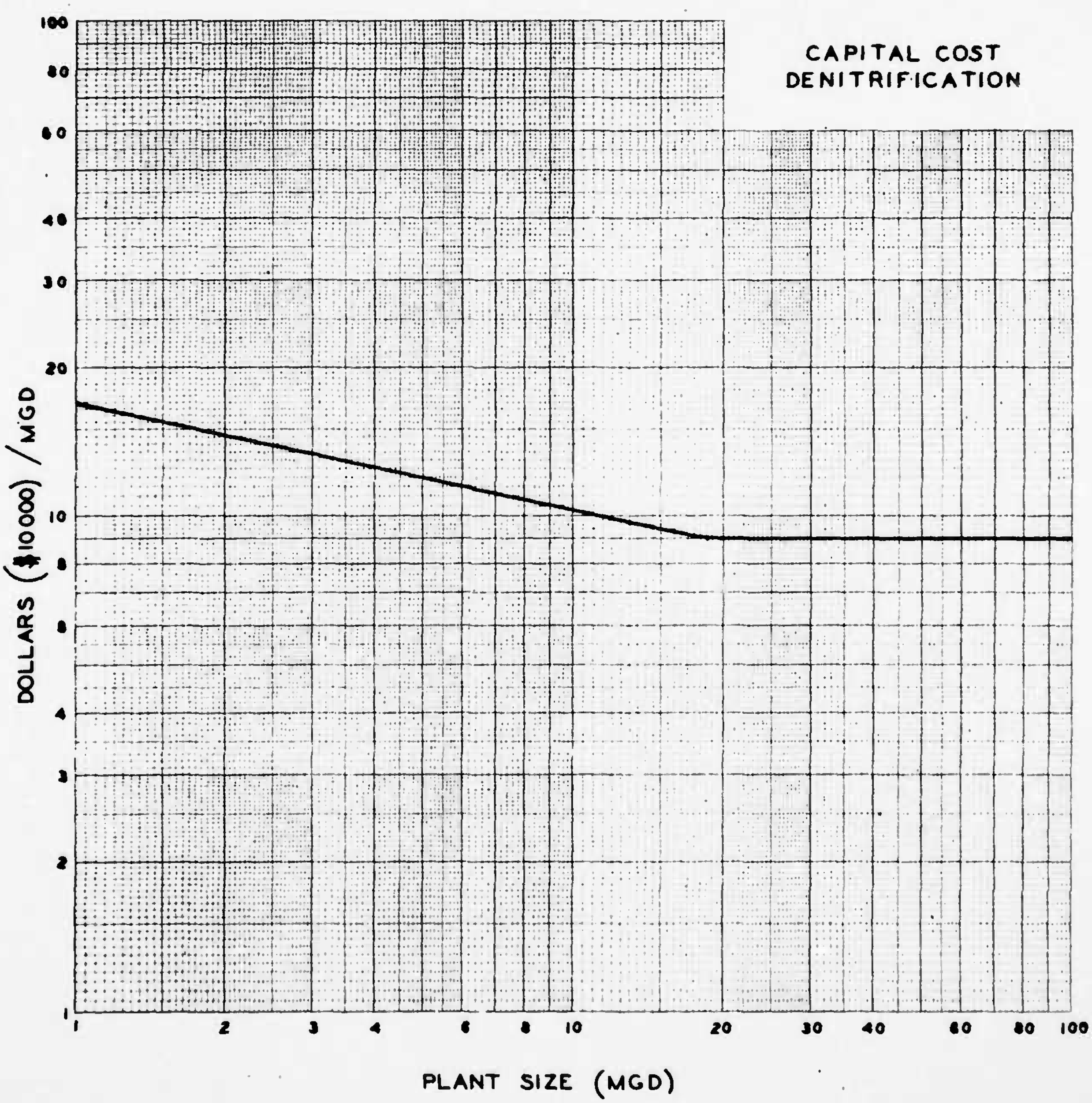

CAPITAL COST
DENITRIFICATION
100
80
60
40
30
20
10
8
6
4
3
2
1
DOLLARS ($10000) / MGD
1
2
3
4
6
8
10
20
30
40
60
80
100
PLANT SIZE (MGD)

Figure No. 16

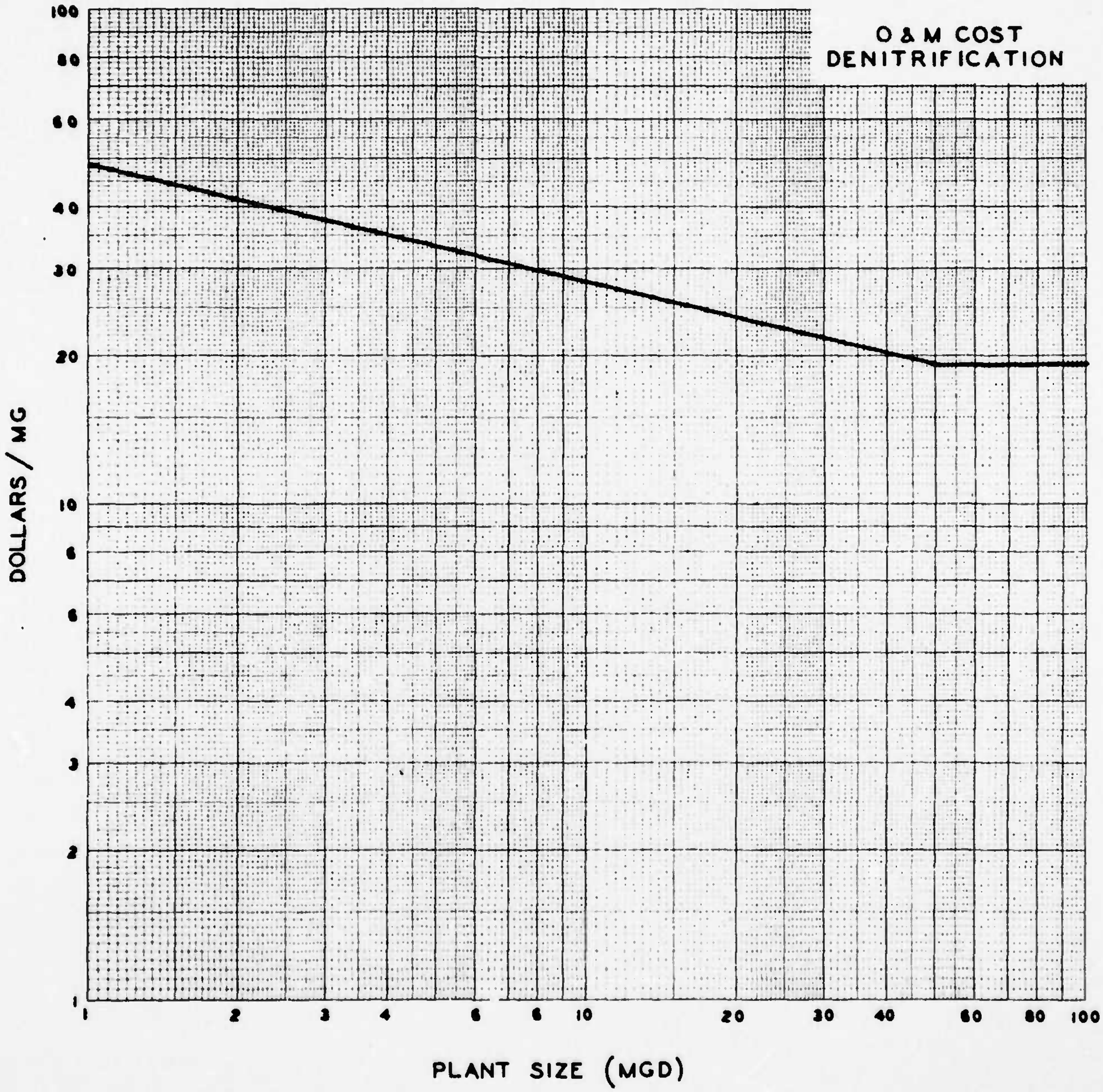


Figure No. 16A

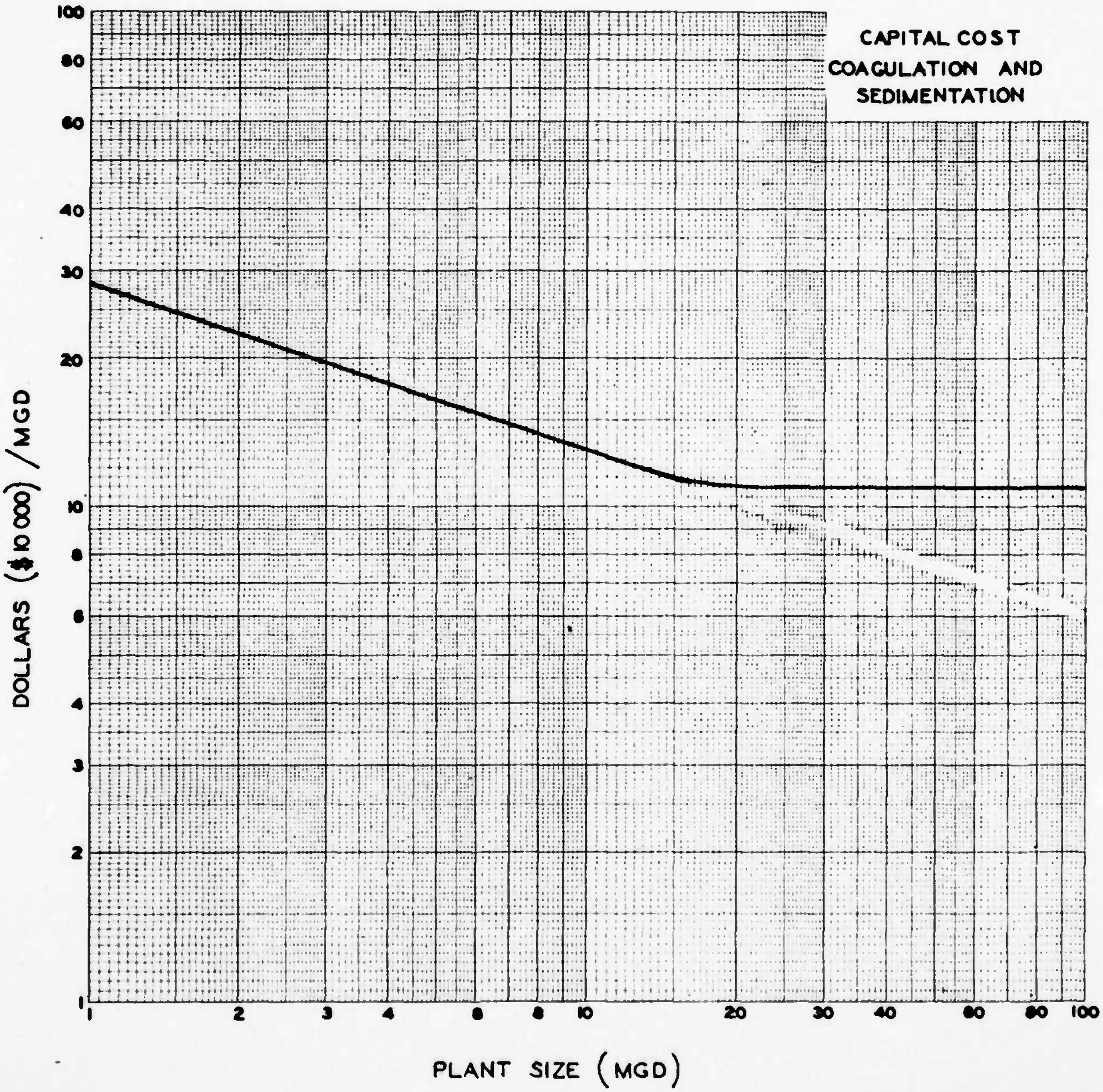

CAPITAL COST
COAGULATION AND
SEDIMENTATION
DOLLARS ($10 000) /MGD
PLANT SIZE (MGD)
100
80
60
40
30
20
10
8
6
4
3
2
1
1
2
3
4
6
8
10
20
30
40
60
80
100

Figure No. 17

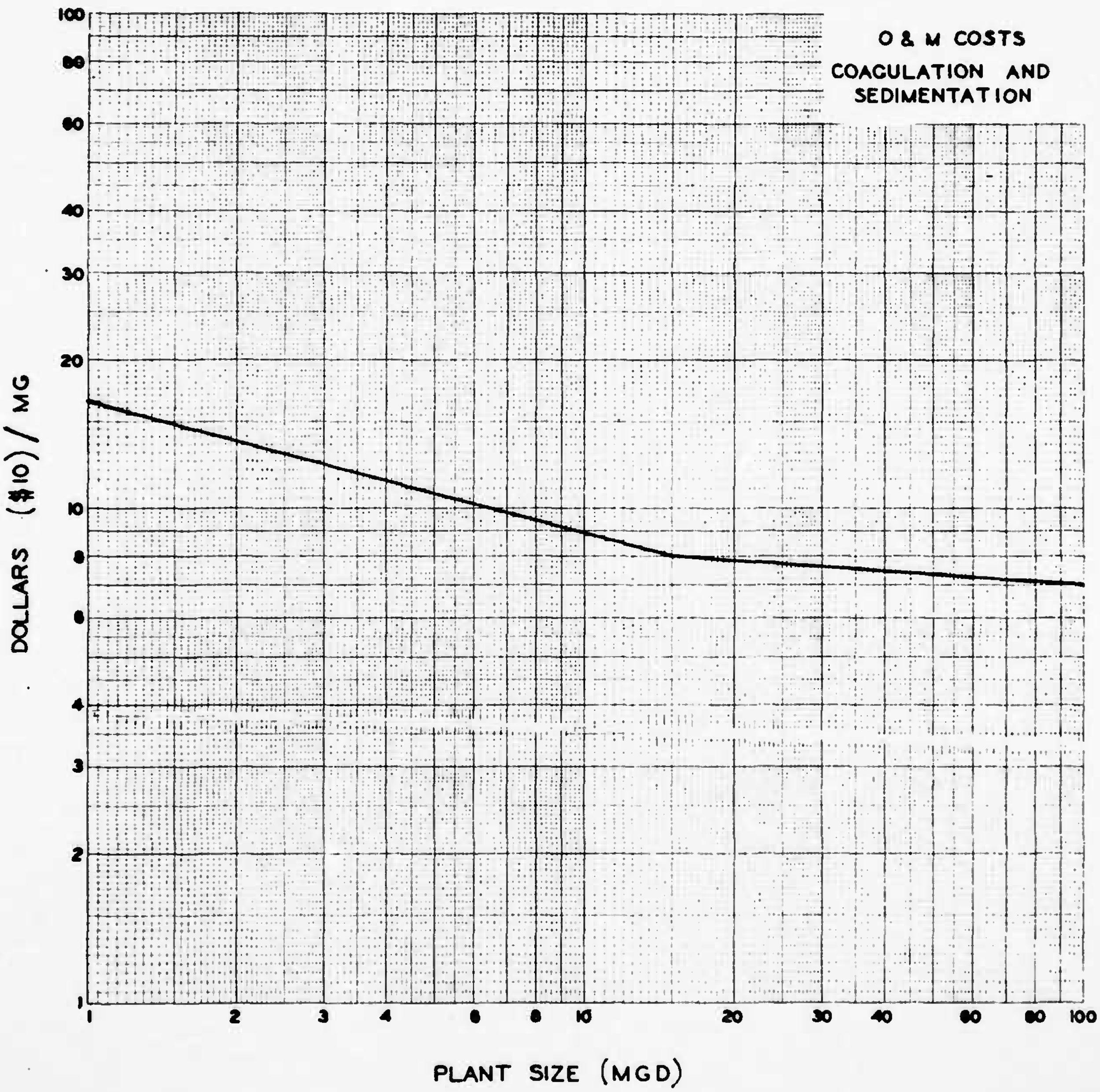


Figure No. 17A

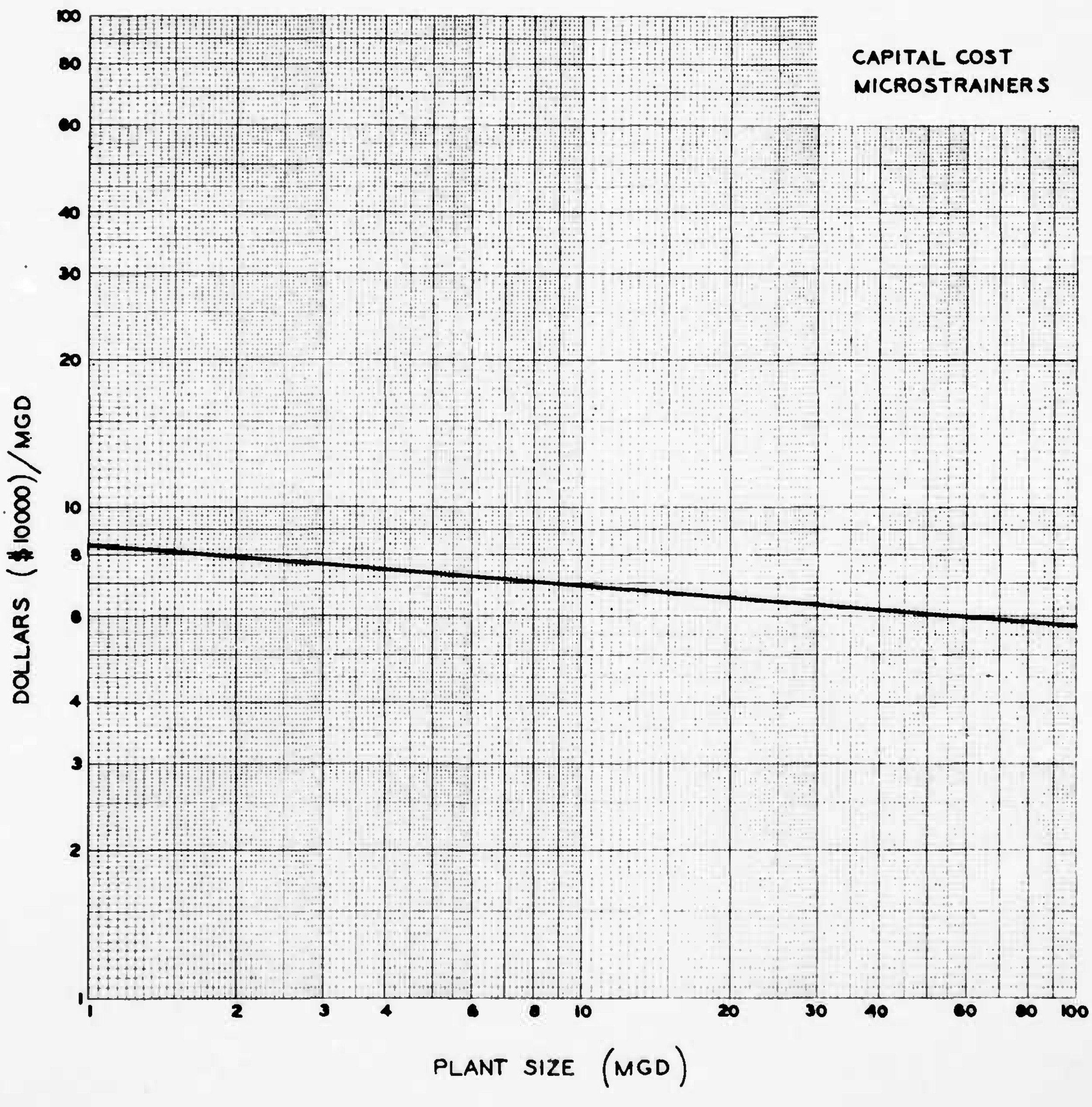

CAPITAL COST
MICROSTRAINERS
DOLLARS ($10000)/MGD
PLANT SIZE (MGD)
100
80
60
40
30
20
10
8
6
4
3
2
1
1
2
3
4
6
8
10
20
30
40
60
80
100

Figure No. 18

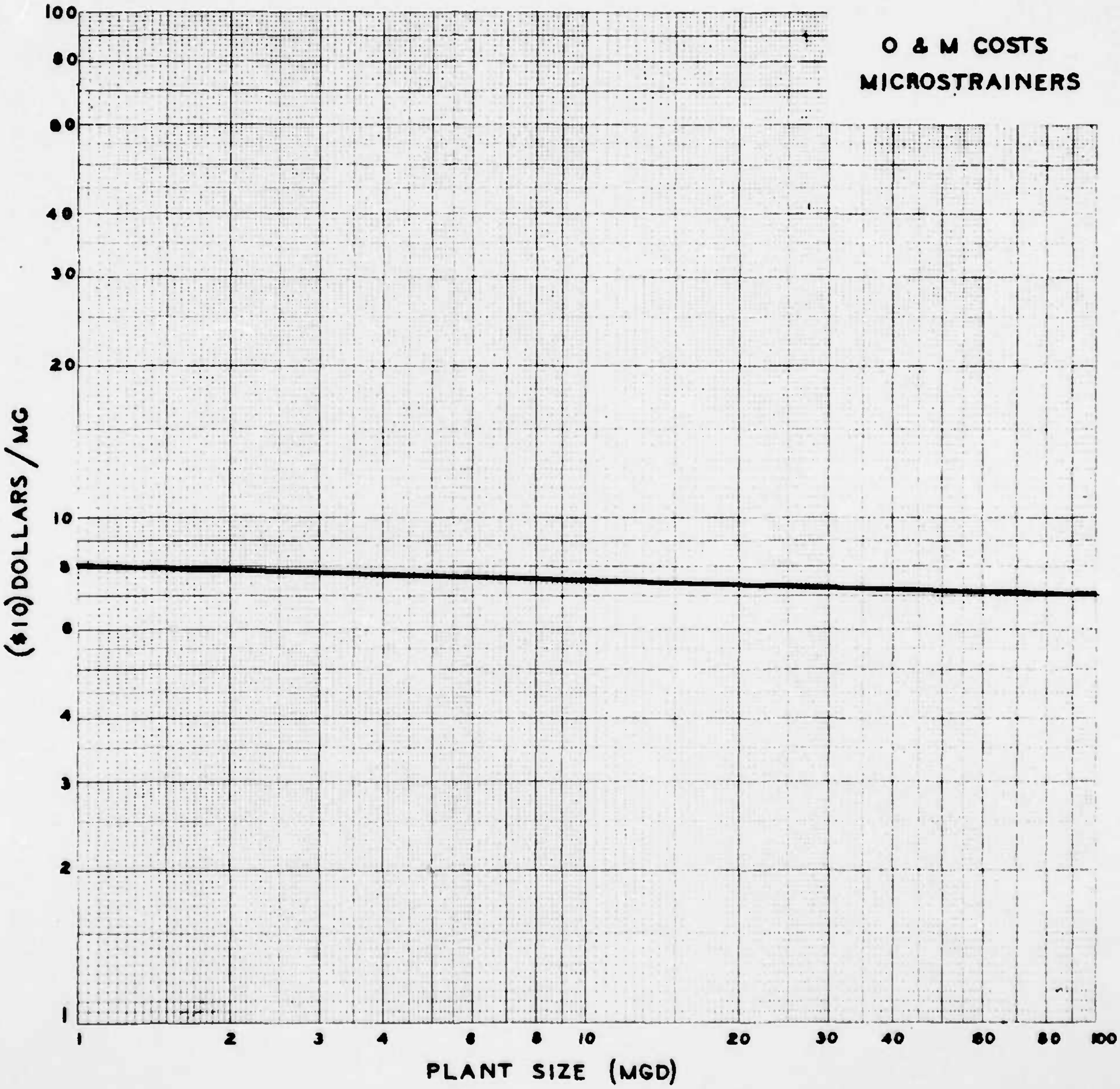


Figure No. 18A

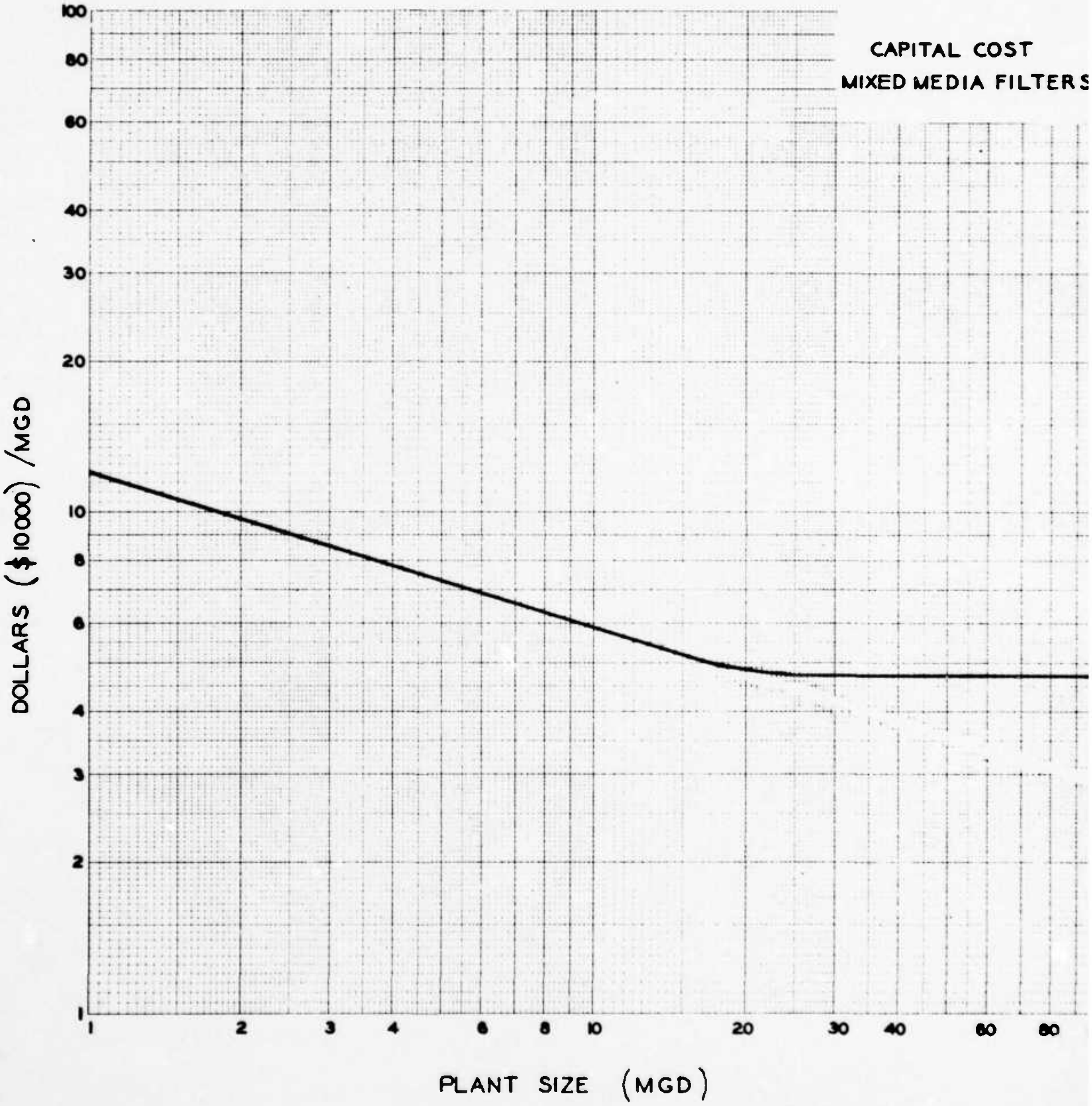

CAPITAL COST
MIXED MEDIA FILTERS
DOLLARS ($10000) /MGD
100
80
60
40
30
20
10
8
6
4
3
2
1
1
2
3
4
6
8
10
20
30
40
60
80
PLANT SIZE (MGD)

Figure No. 19

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WASTEWATER MANAGEMENT ALTERNATIVES FOR THE CLEVELAND - AKRON, T--ETC(U)
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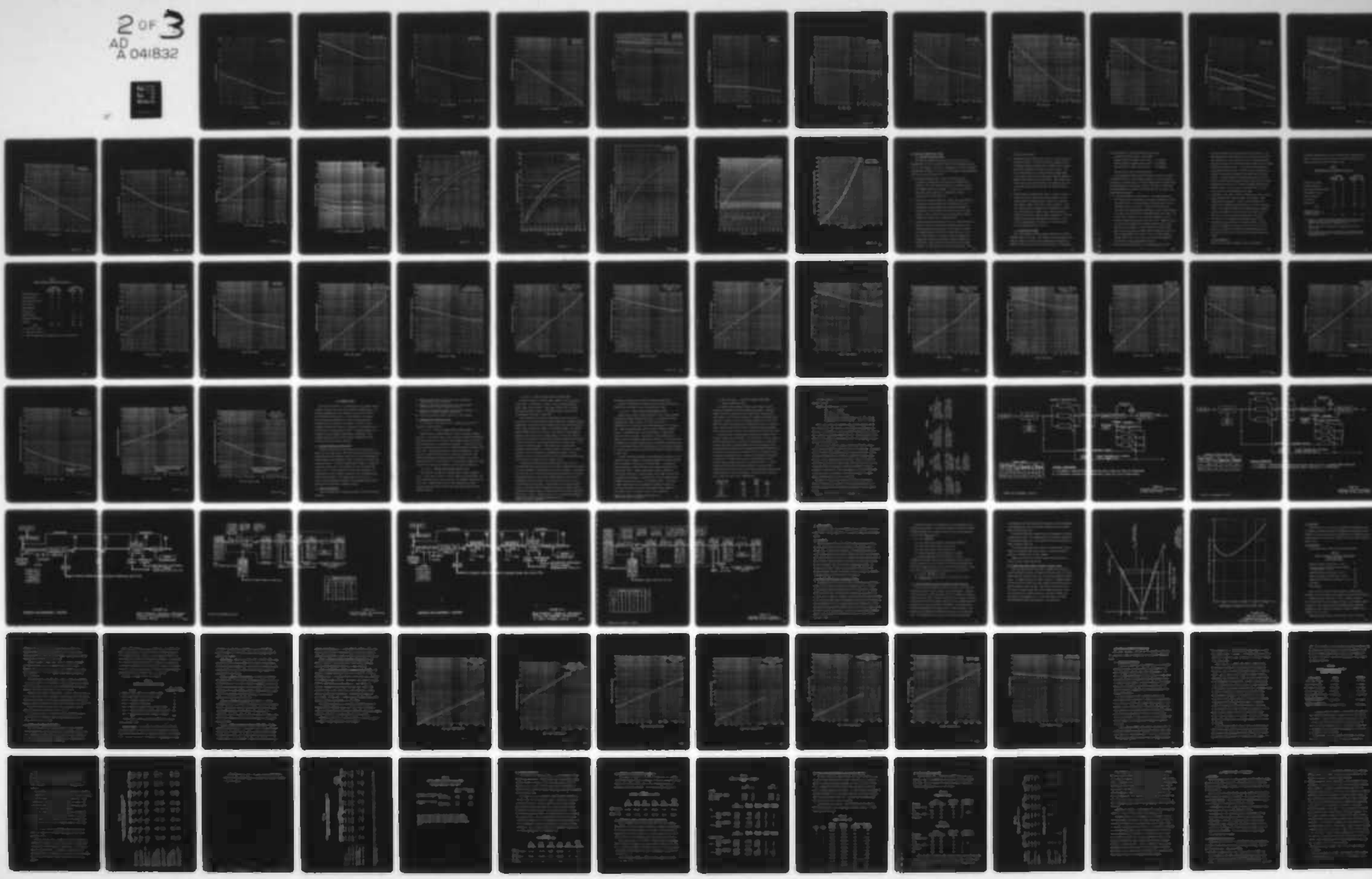

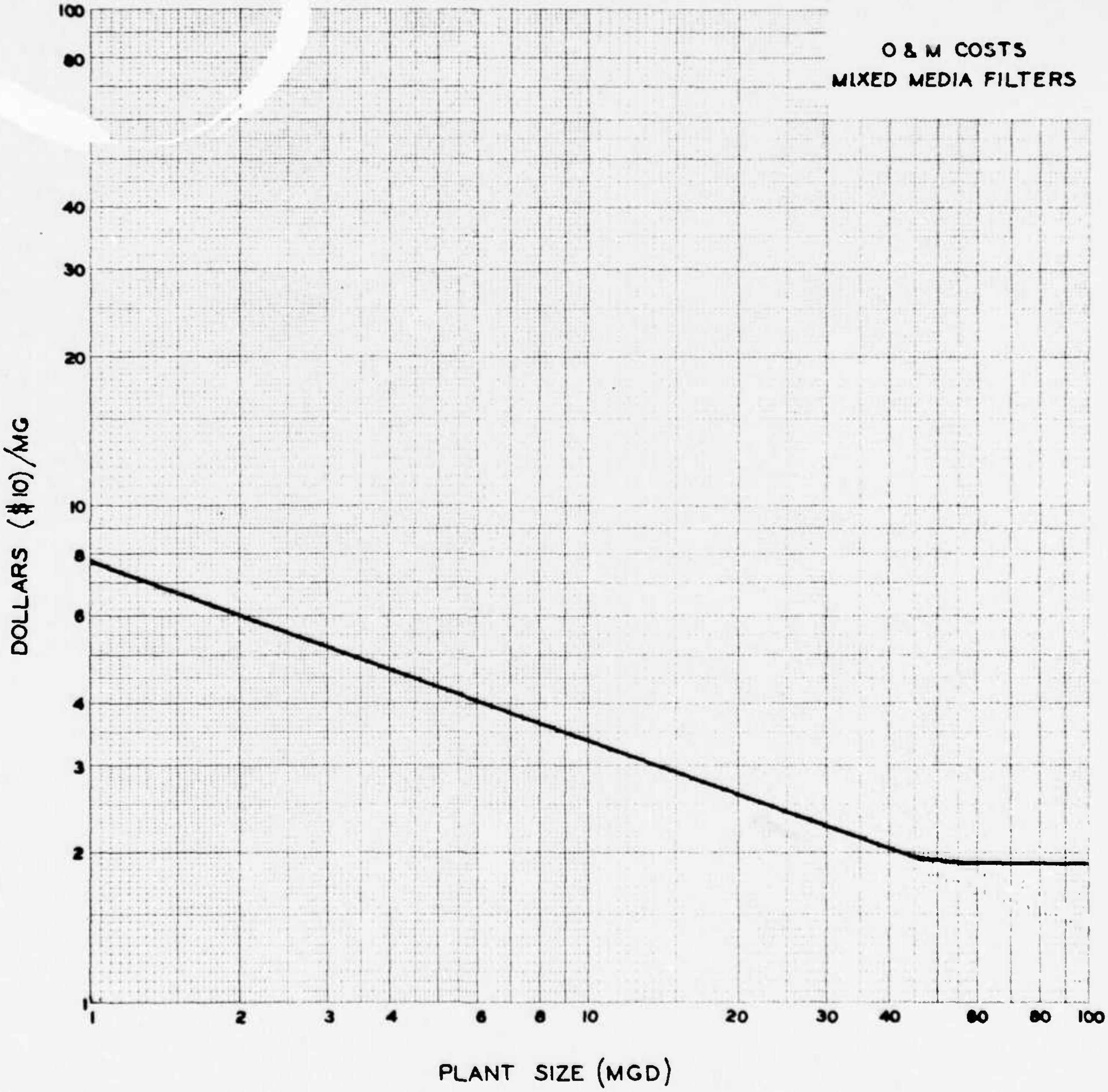

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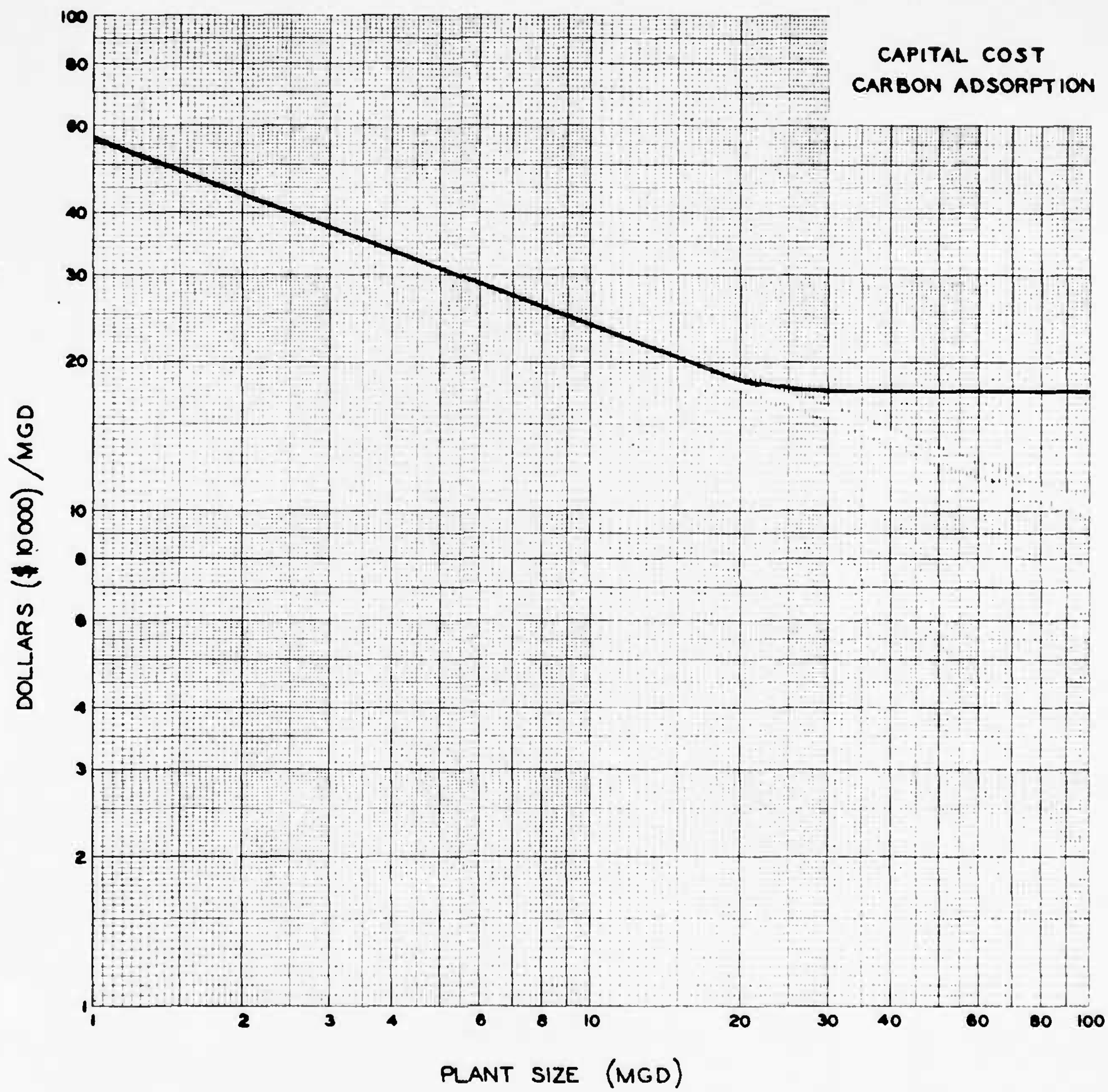


CAPITAL COST
CARBON ADSORPTION
DOLLARS ($10000)/MGD
100
80
60
40
30
20
10
8
6
4
3
2
1
1
2
3
4
6
8
10
20
30
40
60
80
100
PLANT SIZE (MGD)

Figure No. 20

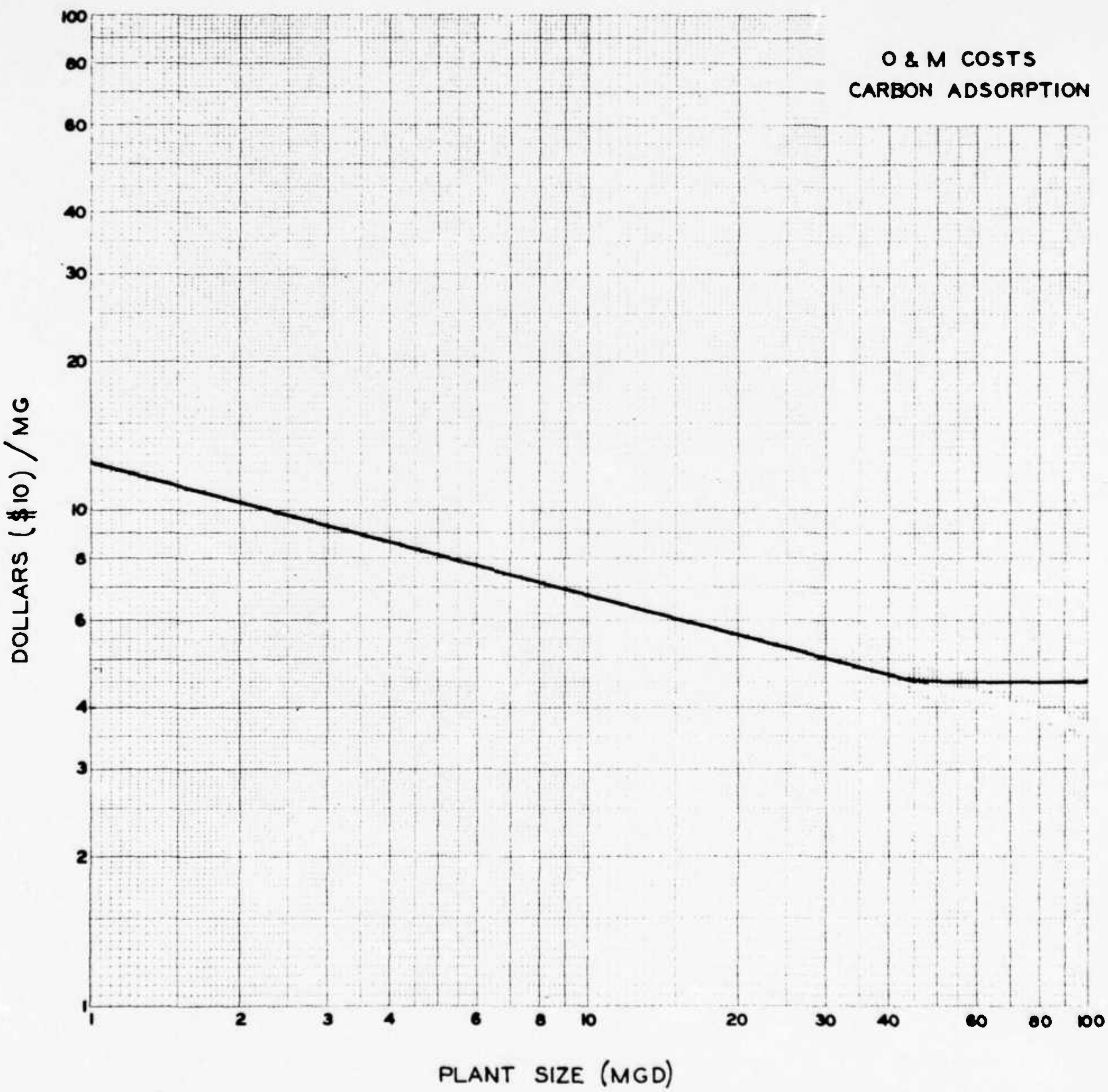


Figure No. 20A

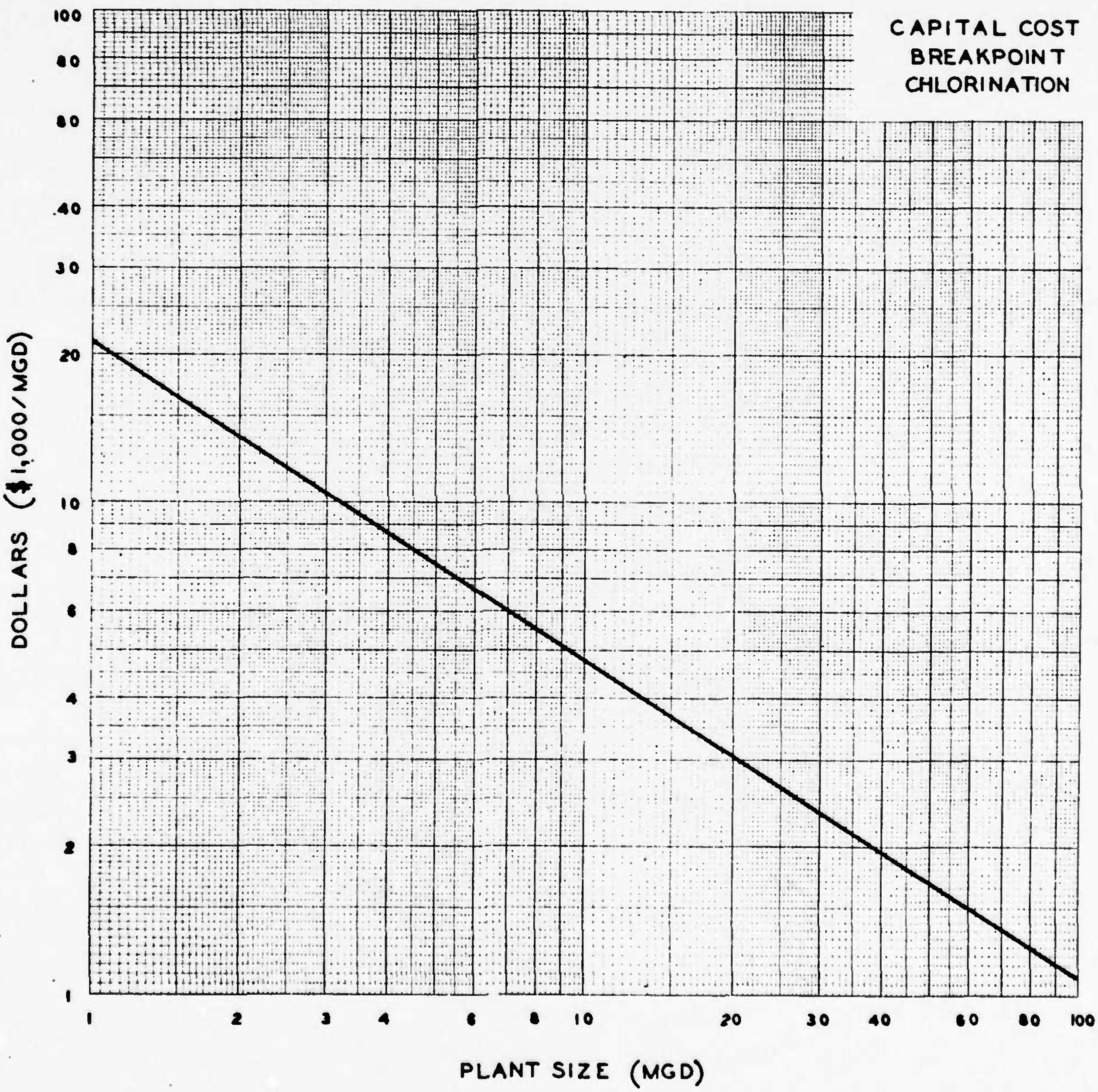

CAPITAL COST
BREAKPOINT
CHLORINATION
DOLLARS ($1,000/MGD)
PLANT SIZE (MGD)
100
80
60
40
30
20
10
8
6
4
3
2
1
1
2
3
4
6
8
10
20
30
40
60
80
100

Figure No. 21

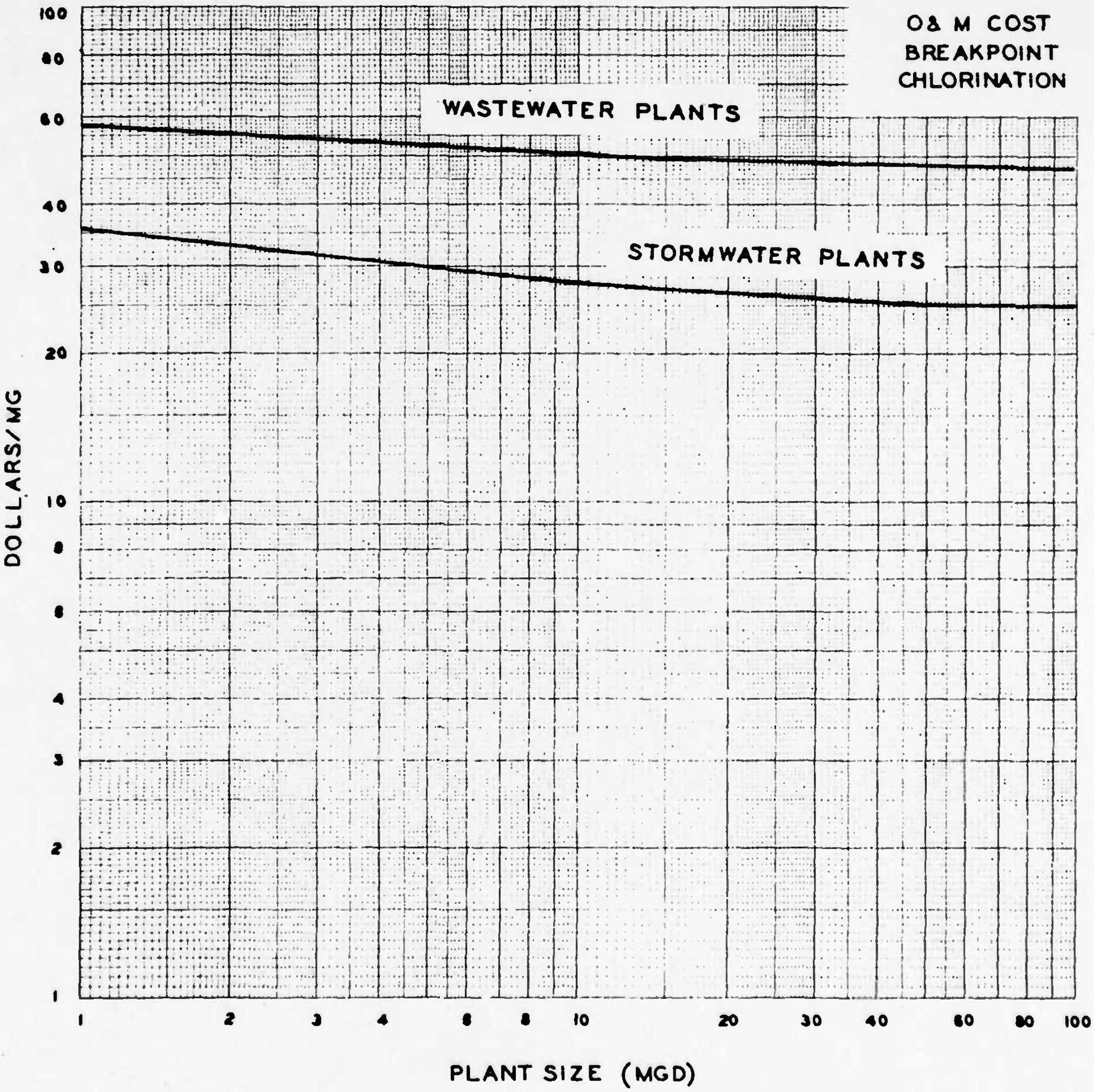


Figure No. 21A

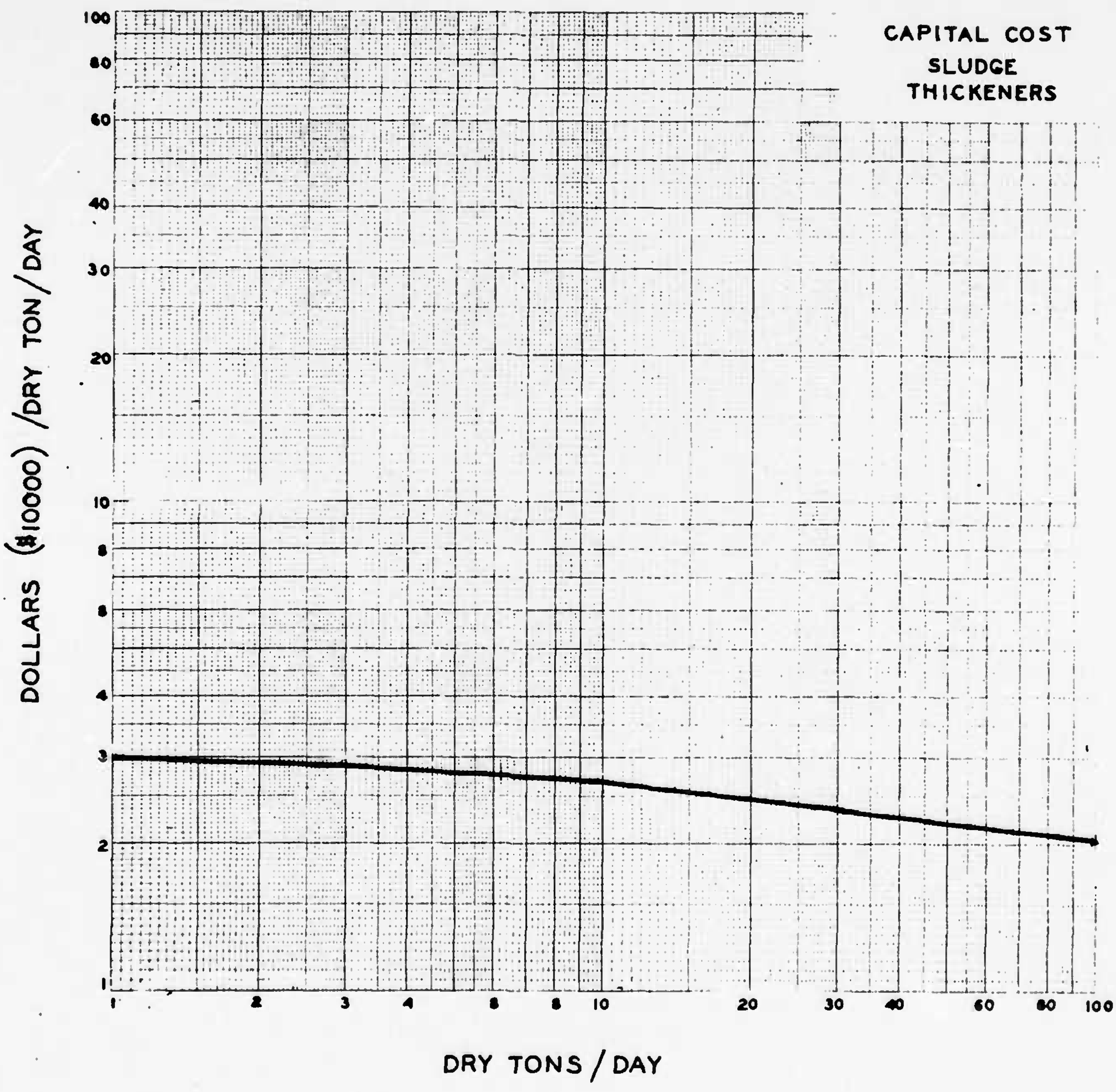

CAPITAL COST
SLUDGE
THICKENERS
DOLLARS ($10000) /DRY TON/DAY
DRY TONS / DAY

Figure No. 22

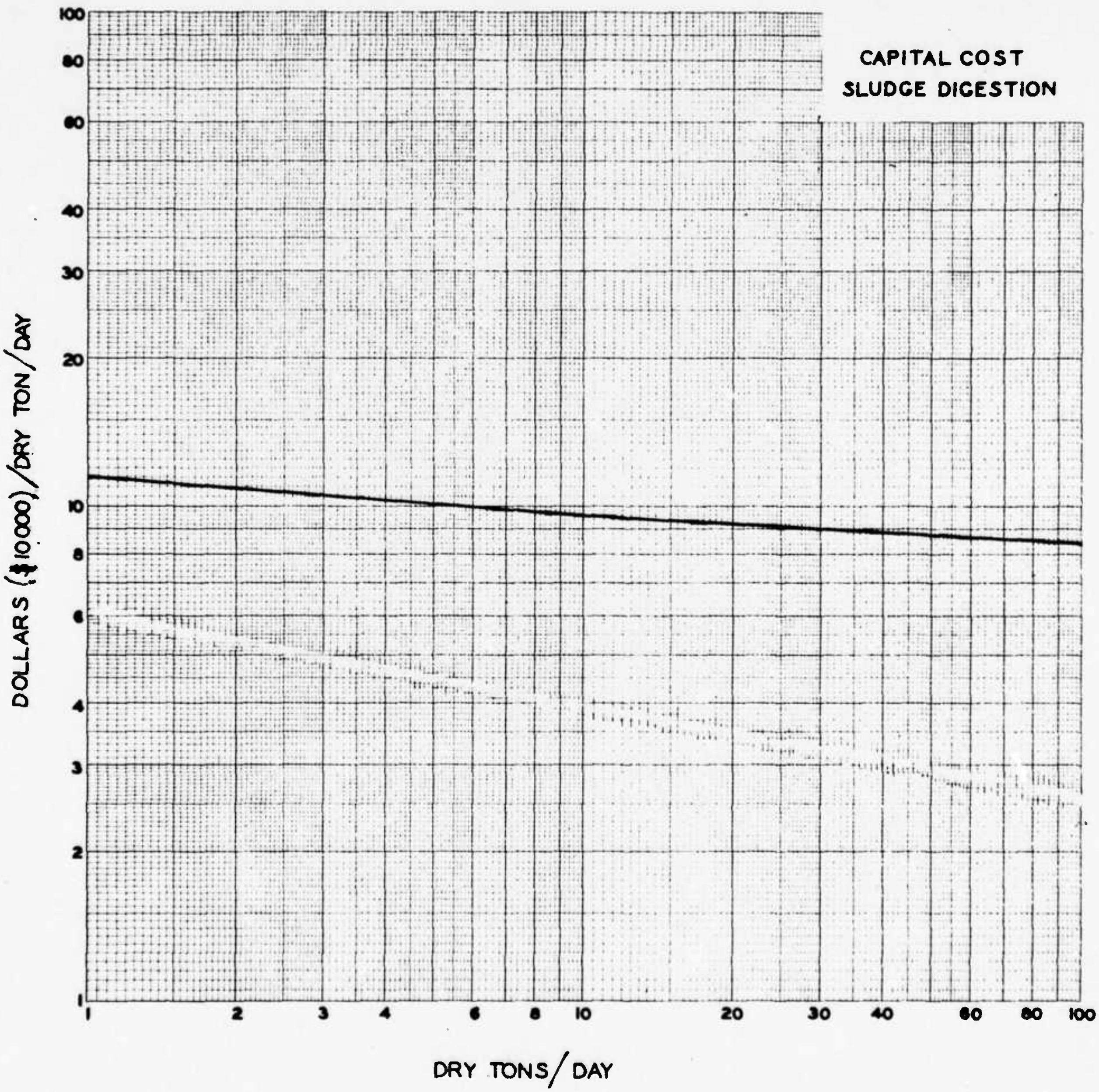

CAPITAL COST
SLUDGE DIGESTION
DOLLARS ($10000)/DRY TON/DAY
100
80
60
40
30
20
10
8
6
4
3
2
1
1
2
3
4
6
8
10
20
30
40
60
80
100
DRY TONS/DAY

Figure No. 23

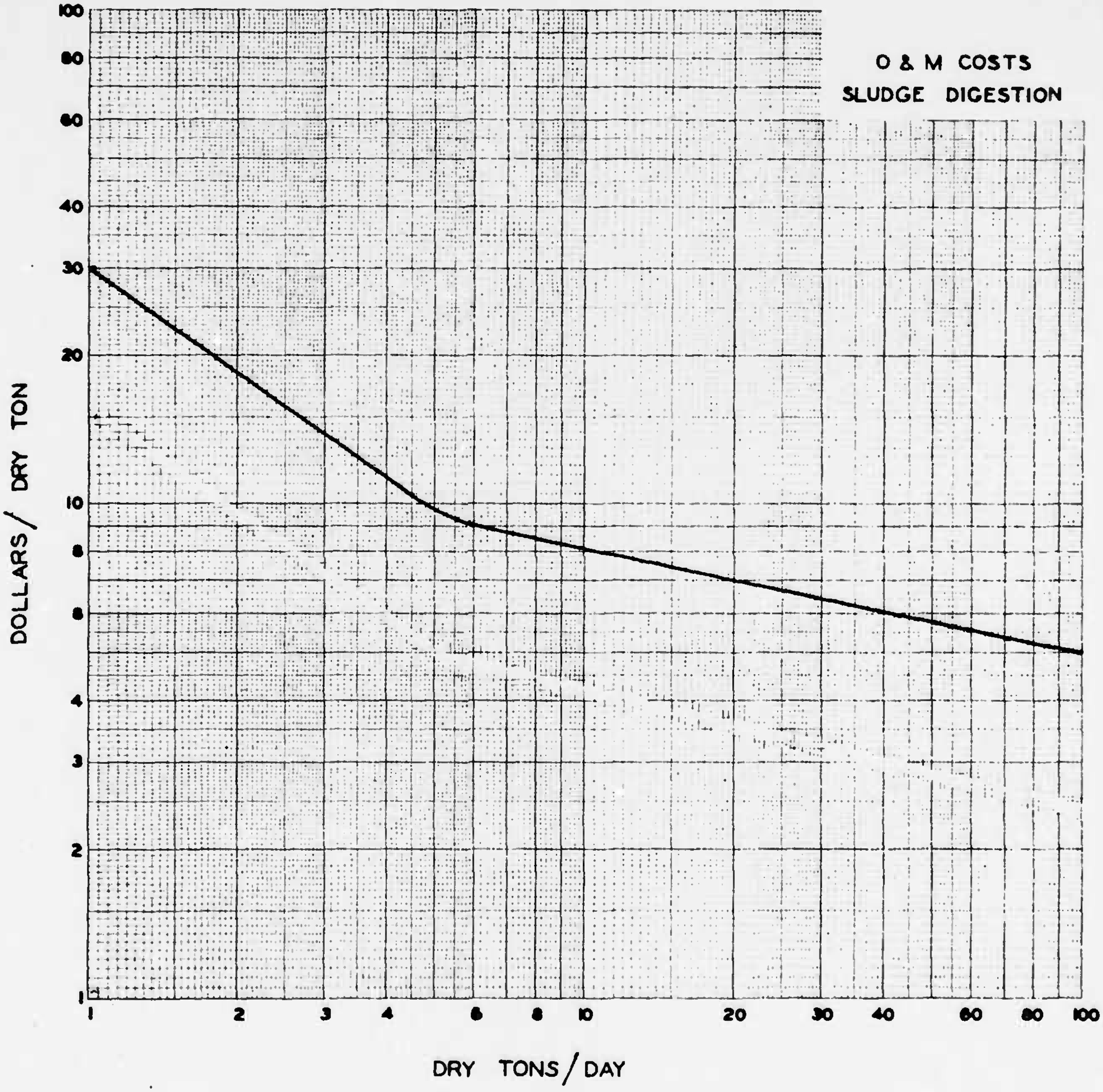


Figure No. 23A

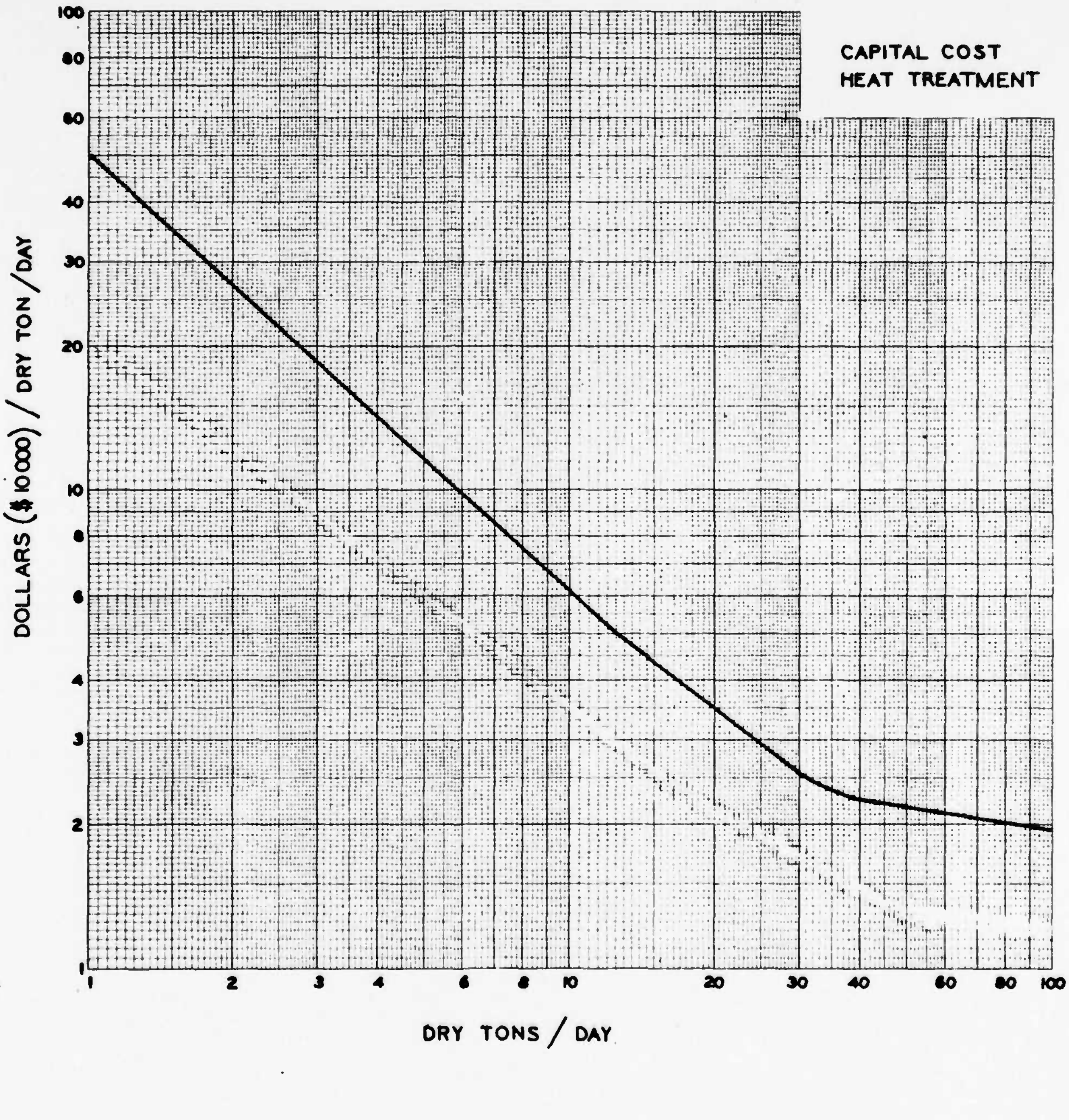

CAPITAL COST
HEAT TREATMENT
DOLLARS ($10000) / DRY TON / DAY
100
80
60
40
30
20
10
8
6
4
3
2
1
1
2
3
4
6
8
10
20
30
40
60
80
100
DRY TONS / DAY

Figure No. 24

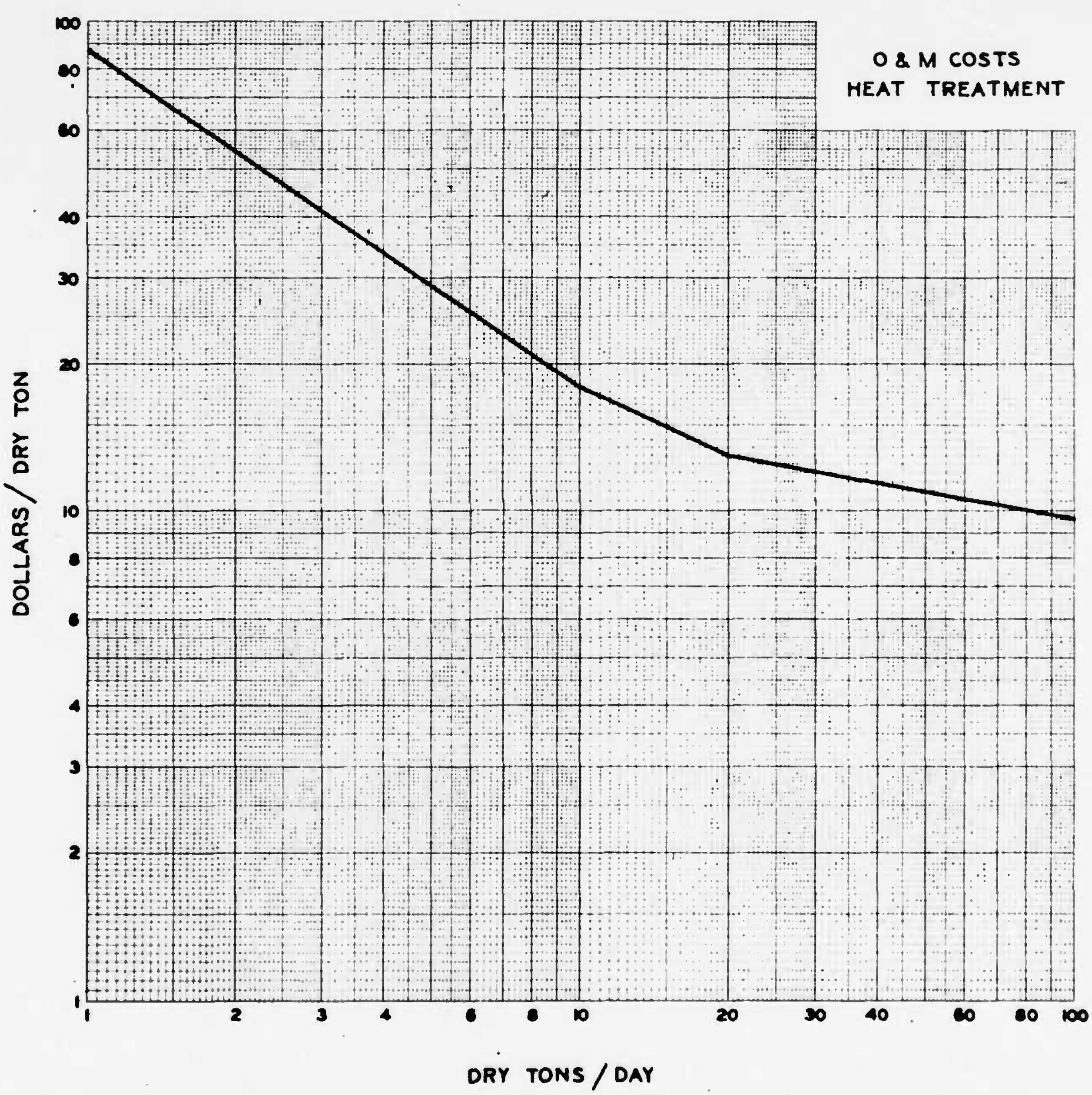


Figure No. 24A

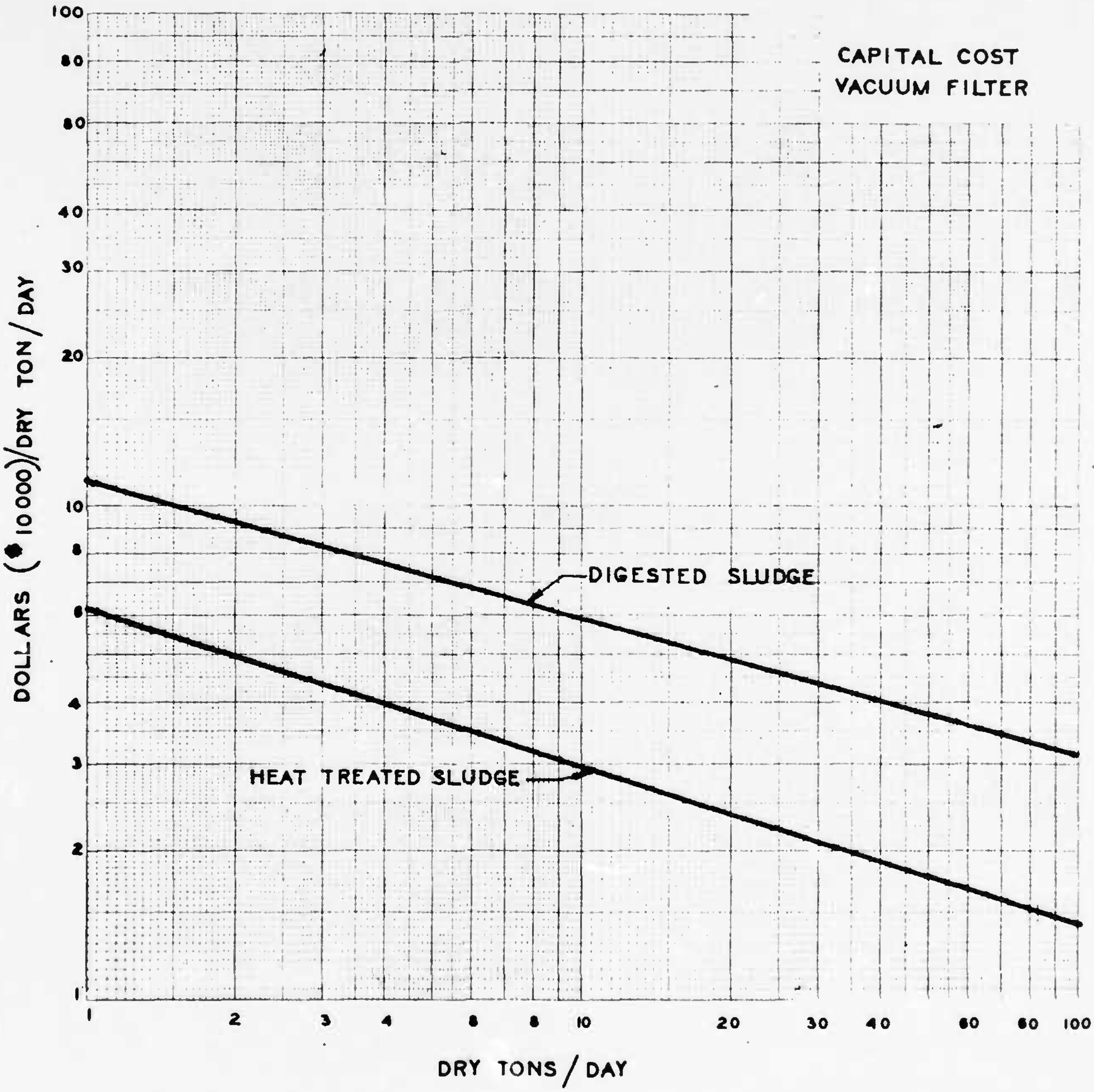

CAPITAL COST
VACUUM FILTER
DIGESTED SLUDGE
HEAT TREATED SLUDGE
DOLLARS ($10000)/DRY TON/DAY
DRY TONS/DAY
100
80
60
40
30
20
10
8
6
4
3
2
1
1
2
3
4
6
8
10
20
30
40
60
80
100

Figure No. 25

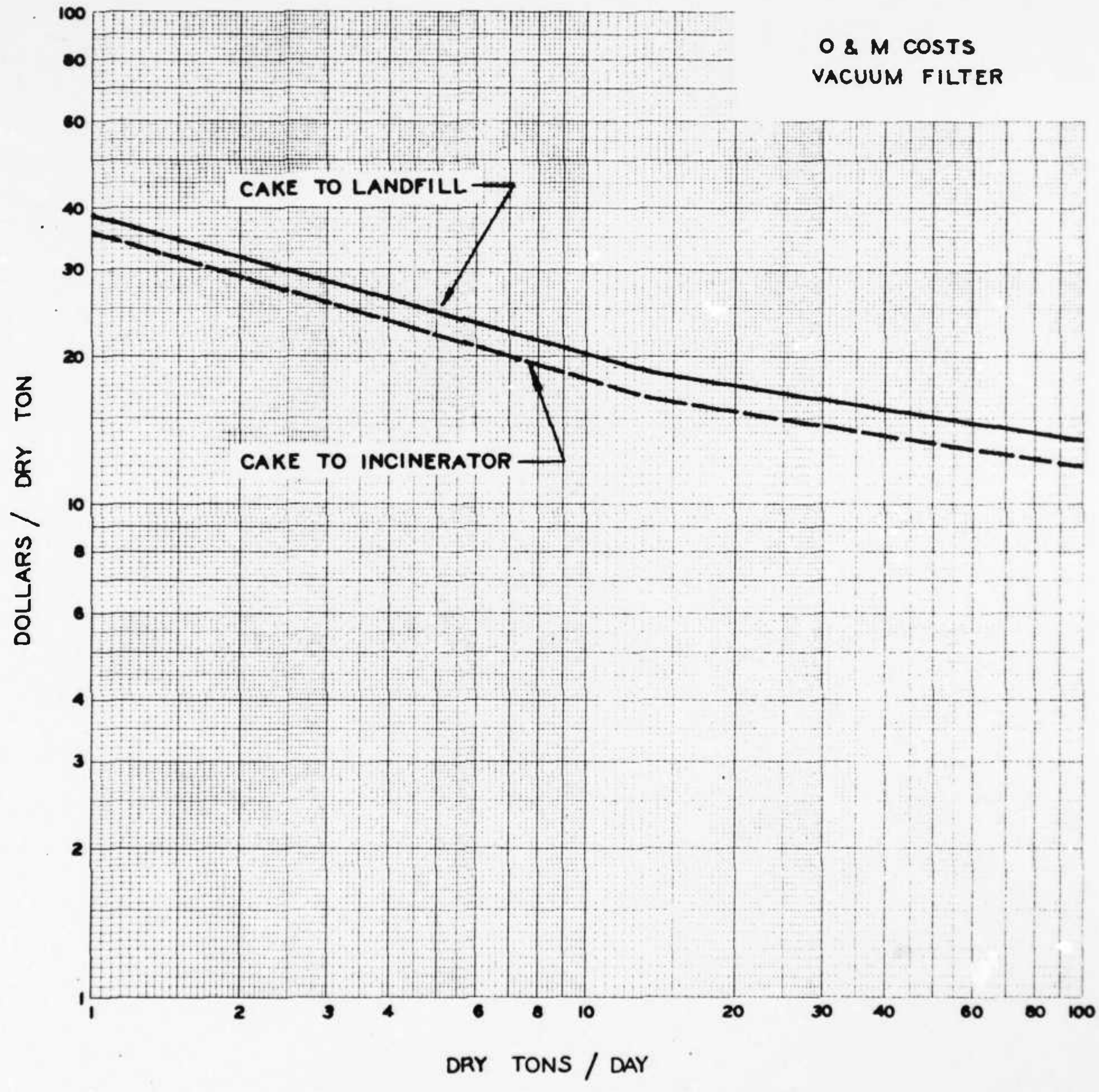
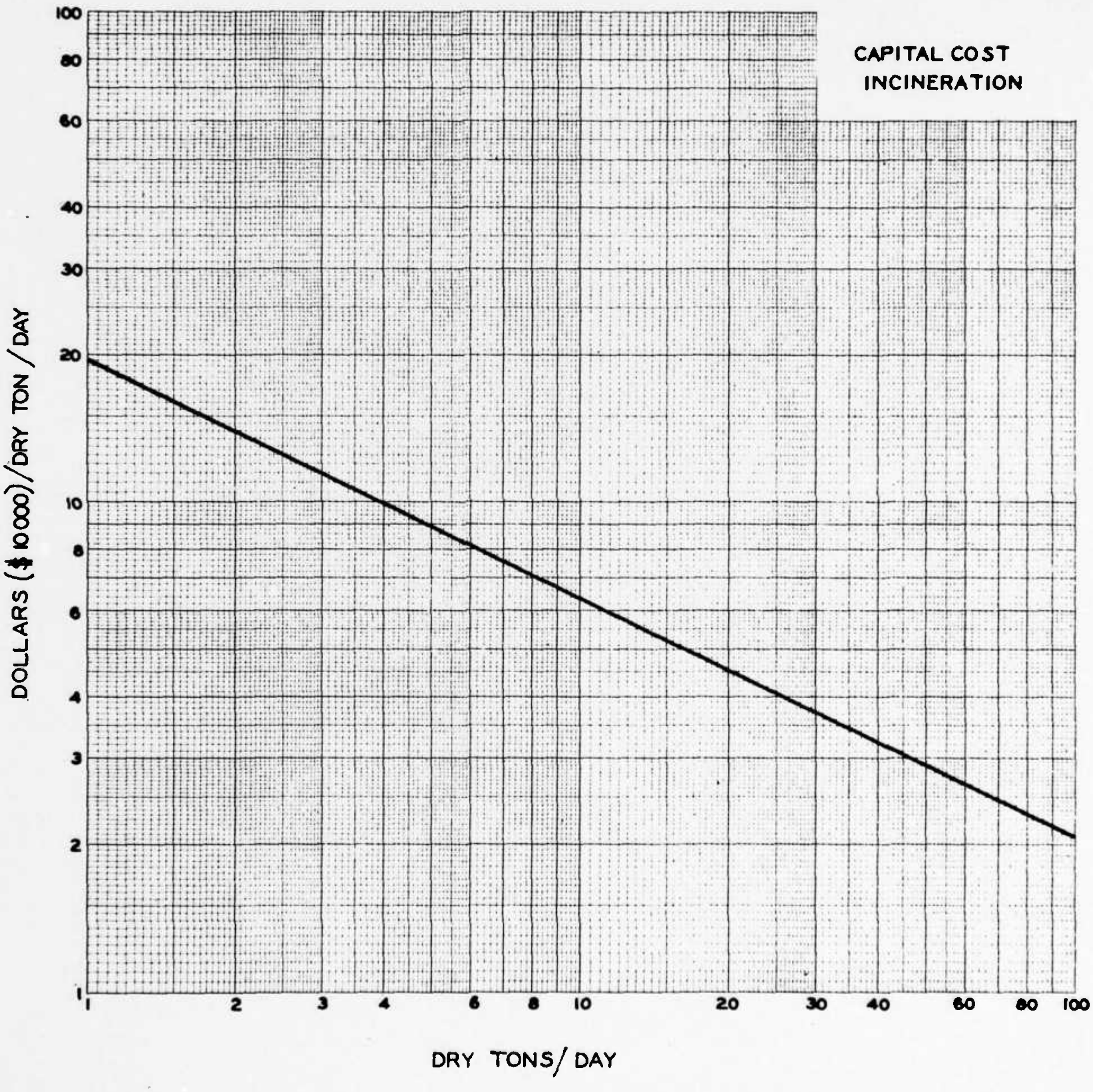


Figure No. 25A



CAPITAL COST
INCINERATION
DOLLARS ($10000)/DRY TON / DAY
100
80
60
40
30
20
10
8
6
4
3
2
1
1
2
3
4
6
8
10
20
30
40
60
80
100
DRY TONS/ DAY

Figure No. 26

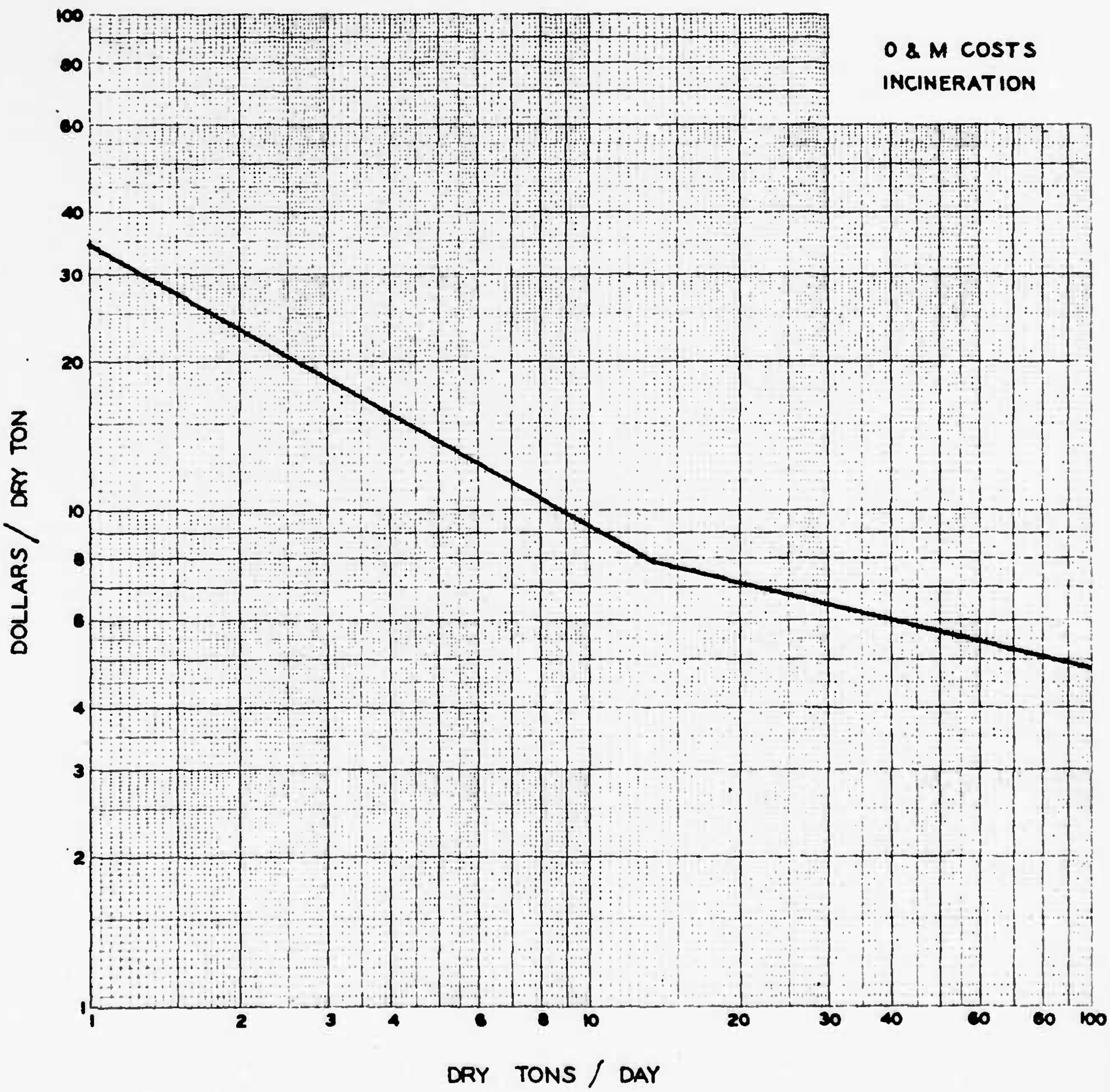


Figure No. 26A

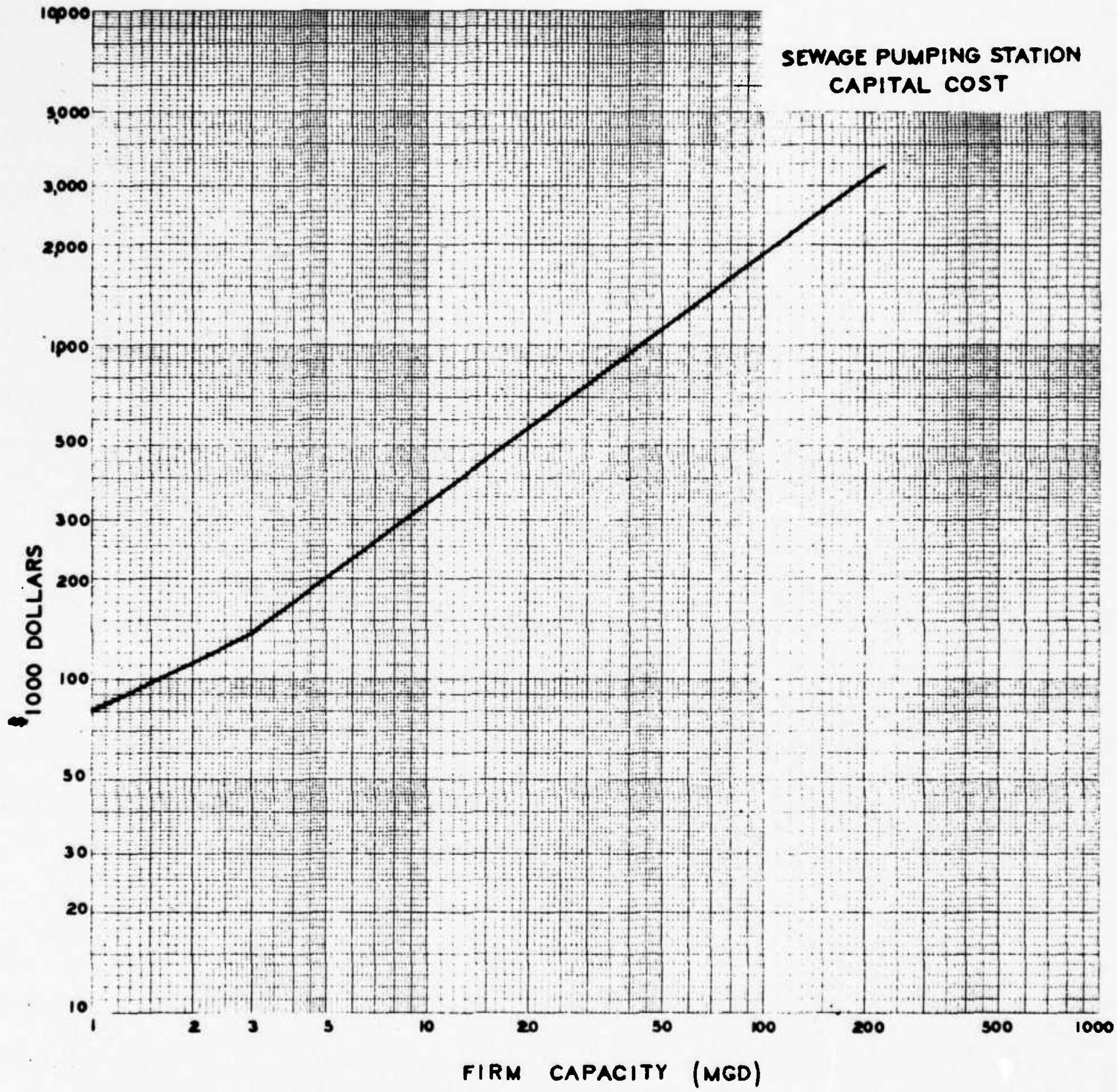

SEWAGE PUMPING STATION
CAPITAL COST
10,000
5,000
3,000
2,000
1,000
500
300
200
100
50
30
20
10
$1000 DOLLARS
1
2
3
5
10
20
50
100
200
500
1000
FIRM CAPACITY (MGD)

Figure No. 27

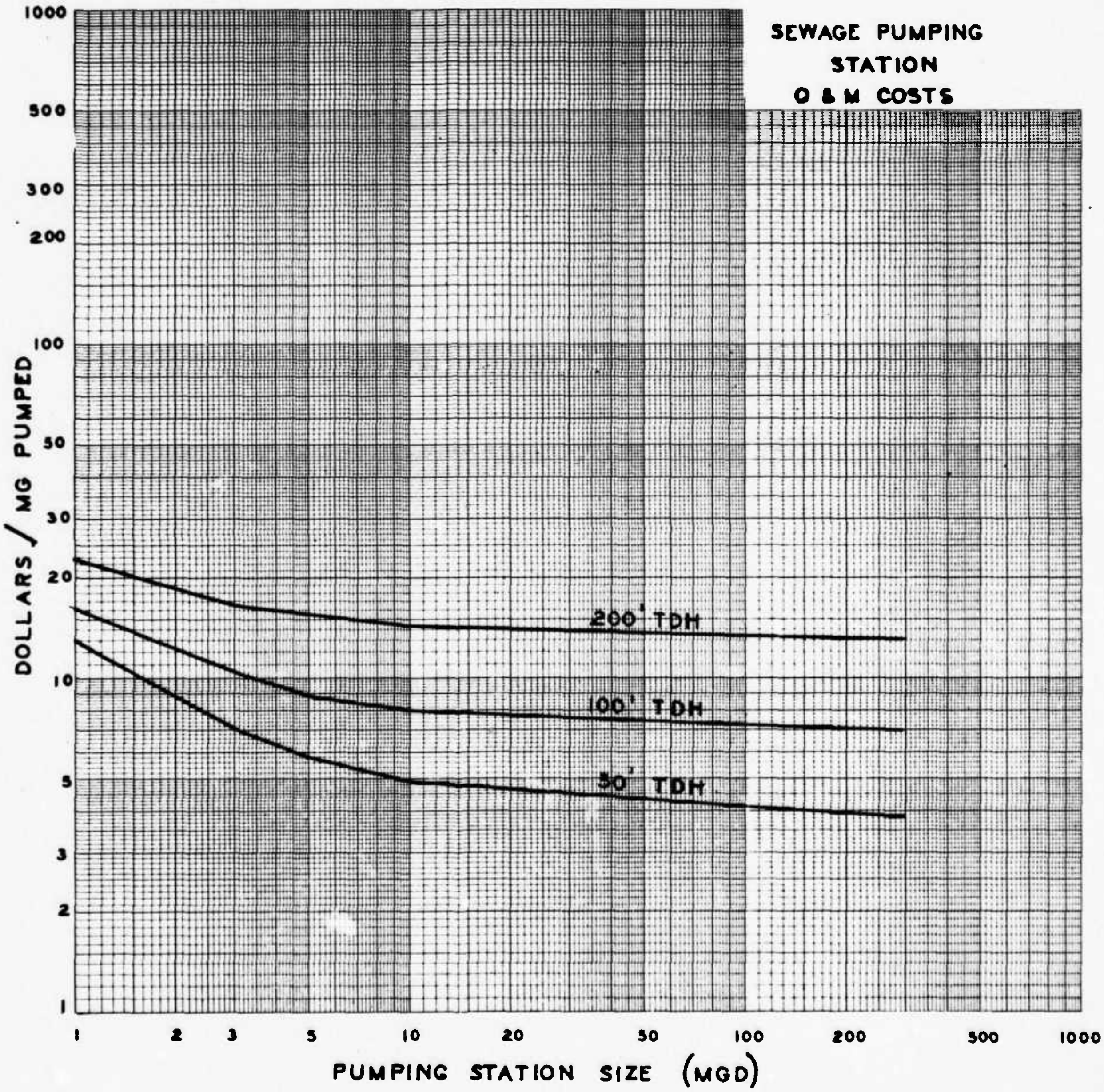


Figure No. 27A

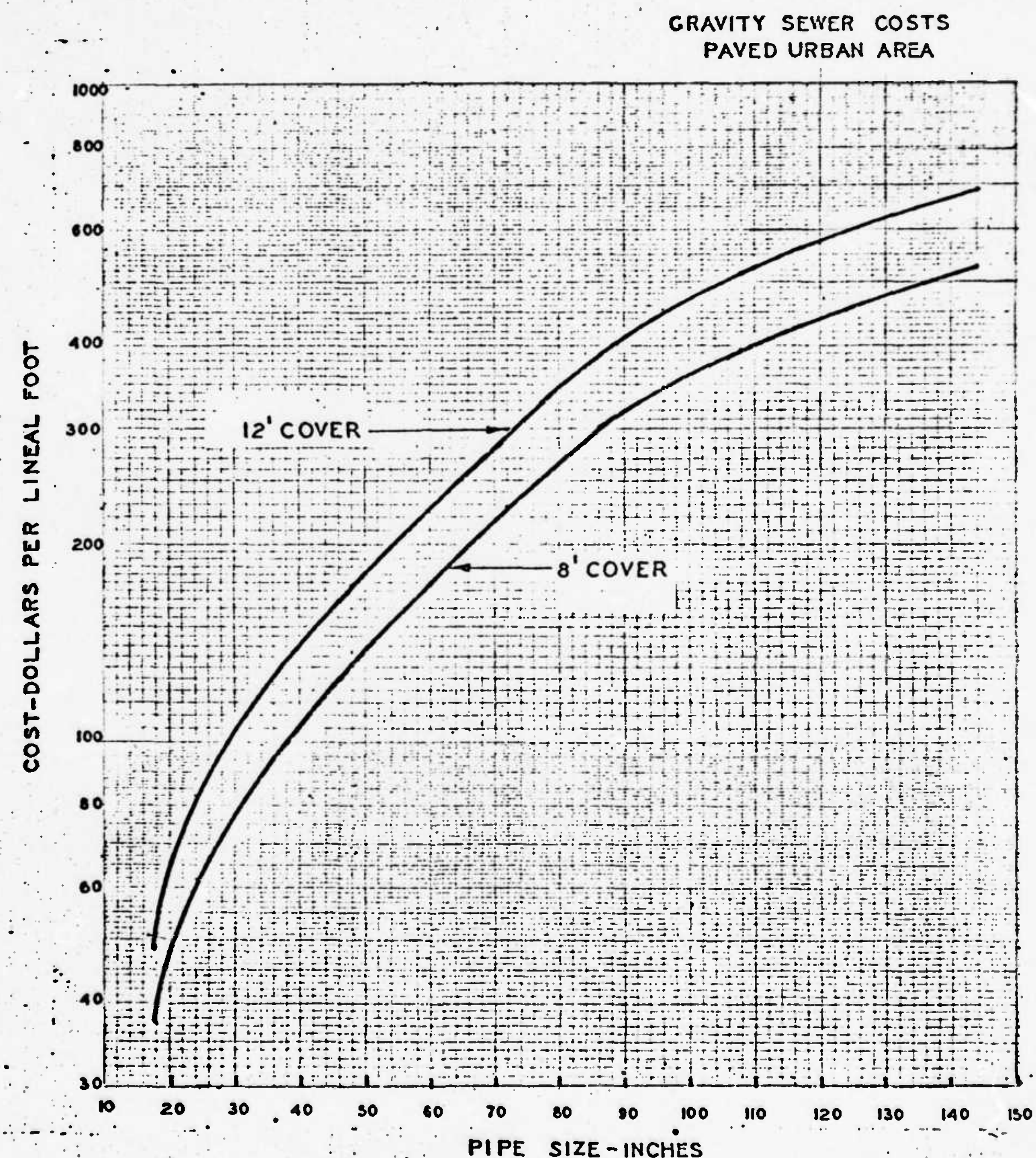

GRAVITY SEWER COSTS
PAVED URBAN AREA
COST-DOLLARS PER LINEAL FOOT
1000
800
600
400
300
200
100
80
60
40
30
12' COVER
8' COVER
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
PIPE SIZE-INCHES

Figure No. 28

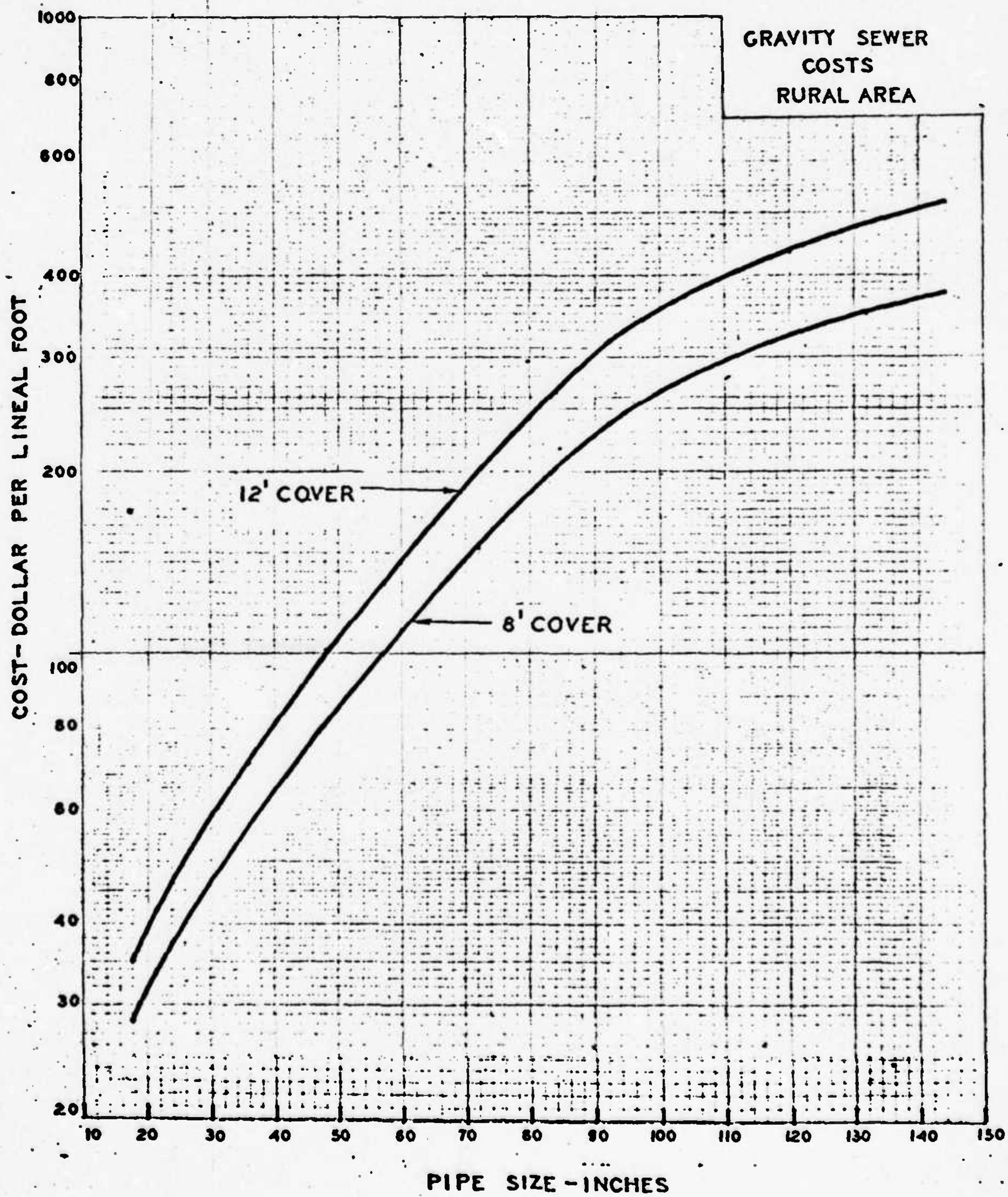

GRAVITY SEWER
COSTS
RURAL AREA
12' COVER
8' COVER
COST-DOLLAR PER LINEAL FOOT
PIPE SIZE-INCHES
1000
800
600
400
300
200
100
80
60
40
30
20
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150

Figure No. 29

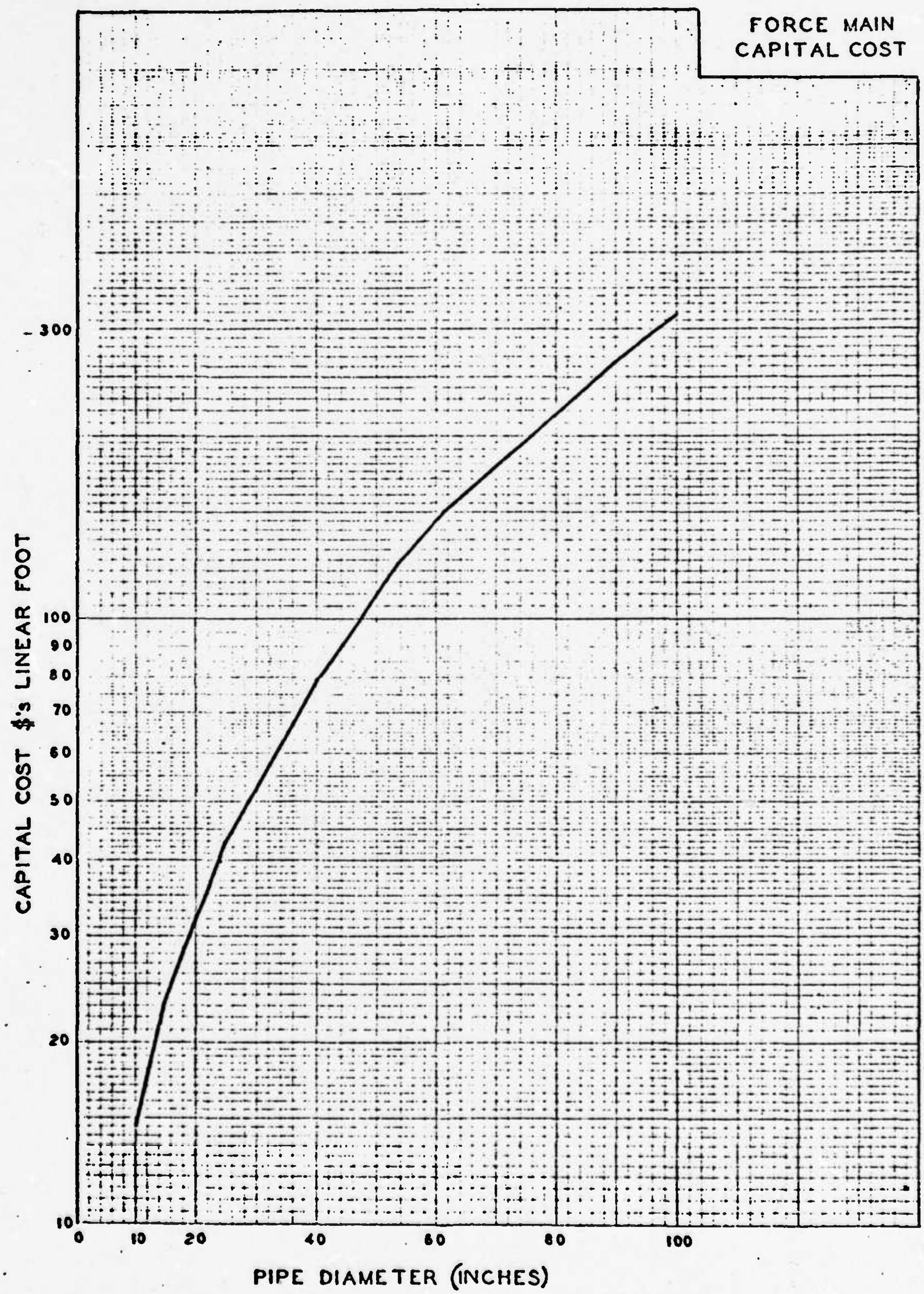

FORCE MAIN
CAPITAL COST
CAPITAL COST $'s LINEAR FOOT
300
100
90
80
70
60
50
40
30
20
10
0
10
20
40
60
80
100
PIPE DIAMETER (INCHES)

Figure No. 30

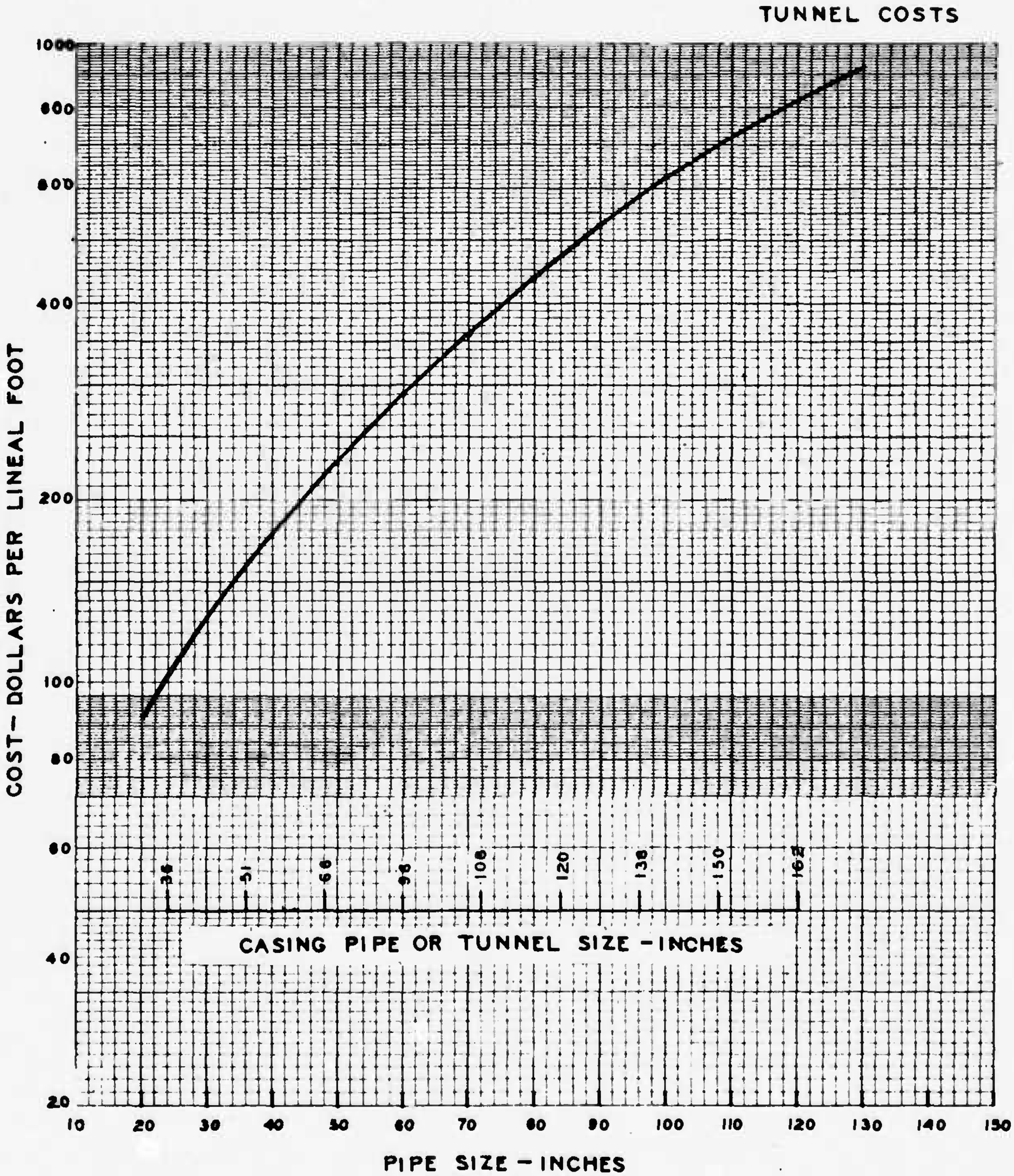

TUNNEL COSTS
COST - DOLLARS PER LINEAL FOOT
1000
800
600
400
200
100
80
60
40
20
36
51
66
96
108
120
138
150
162
CASING PIPE OR TUNNEL SIZE - INCHES
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
PIPE SIZE - INCHES

Figure No. 31

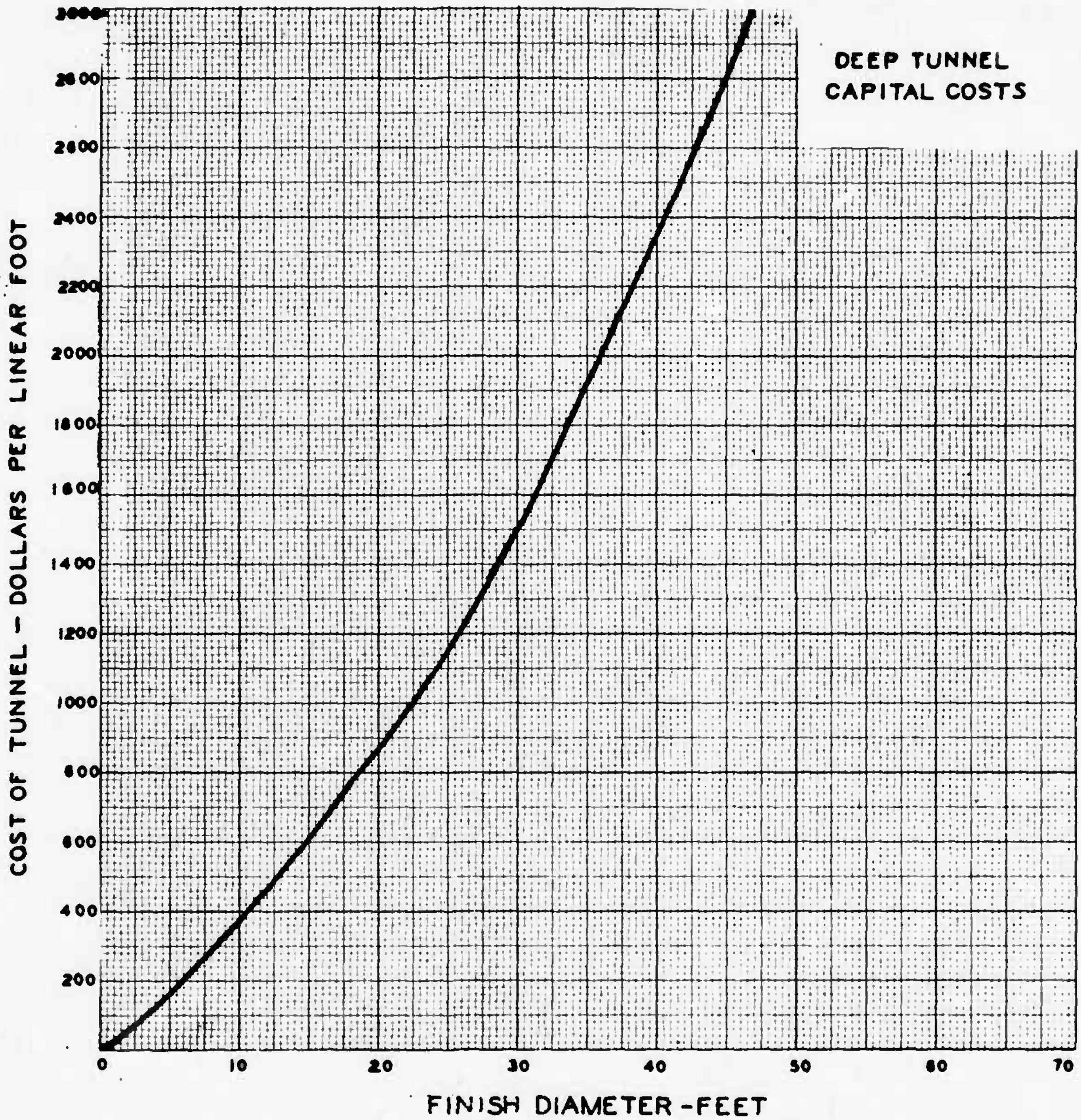

DEEP TUNNEL
CAPITAL COSTS
COST OF TUNNEL - DOLLARS PER LINEAR FOOT
FINISH DIAMETER -FEET
200
400
600
800
1000
1200
1400
1600
1800
2000
2200
2400
2600
2800
3000
0
10
20
30
40
50
60
70

Figure No. 32

4. MUNICIPAL TREATMENT PLANT DESIGN

4.1 WASTEWATER TREATMENT SCHEMES

The municipal treatment plant design varied from plan to plan depending upon the level of treatment required or the designated treatment prior to land treatment. Following is a description of the five wastewater treatment plant variations. Cost curves were developed by adding appropriate unit process costs from Figures 11-32.

1) Preliminary Treatment Plant - Figures 33 and 33A represent the capital and operation and maintenance cost for preliminary treatment. This cost includes facilities for screening, aerated grit chambers, and flow measurement. This cost was used in those plans where aerated lagoons were the method of secondary treatment prior to land application.

2) Conventional Activated Sludge Plant - Figures 34 and 34A represent the capital cost and the operation and maintenance cost for a conventional activated sludge plant including disinfection by chlorination. This curve does not reflect any costs for sludge handling. These costs were used in those plans where secondary treatment was required prior to land application.

3) Advanced Biological Treatment Plant (Level 1) - Figures 35 and 35A represent the capital and operation and maintenance cost for an advanced biological treatment plant to achieve Level 1 criteria. The schematic diagram of this plant is shown in Figure 5. The costs include those for a conventional activated sludge plant, nitrification, mixed media filtration, phosphorus removal, and chlorination. These curves do not reflect any cost for sludge handling. This plant was used in all Level 1 plans where a water

based plant was required.

4) Advanced Biological Treatment Plant (Level 2) - Figures 36 and 36A represent the capital cost and operation and maintenance cost for an advanced biological treatment plant to achieve Level 2 criteria. The schematic diagram of this plant is shown in Figure 7. The costs include those for a conventional activated sludge plant, nitrification, denitrification, mixed media filtration, phosphorus removal, carbon adsorption, and chlorination. These curves do not reflect any costs for sludge handling. This plant was used on all Level 2 plans where a water based plant was required except for Plan 11.

5) Physical-Chemical Treatment Plant (Level 2) - Figures 37 and 37A represent the capital and operation and maintenance cost for a physical-chemical treatment plant to achieve Level 2 criteria. The schematic diagram of this plant is shown in Figure 8. These costs include those for coagulation and sedimentation (two stage lime clarification), mixed media filters, carbon adsorption, breakpoint chlorination, downflow carbon, and ozonation. The curve includes cost for sludge dewatering and recalcination. Costs do not include handling of the waste ash. This plant was used for all water-based plants in Plan 11.

4.2 SLUDGE HANDLING SCHEMES

Each of the wastewater treatment schemes described above generate different quantities of sludge. By referring to the mass diagrams of the treatment schemes, the sludge quantities generated were determined in TPD/MGD (Dry Tons per Day per million gallons per day). The following

lists the quantities of sludge generated for each scheme:

Conventional Activated Sludge: 0.645 TPD/MGD

Advanced Biological Treatment Plant (Level 1): 1.06 TPD/MGD

Advanced Biological Treatment Plant (Level 2): 1.14 TPD/MGD

Physical-Chemical Treatment Plant (Level 2): 0.86 TPD/MGD*

*TPD of waste ash from recalcination furnace.

The sludge handling technique varied from plan to plan as described in the Formulation Phase 1, Synopsis Report, prepared by the Plan Formulators. Following is a brief description of the four sludge disposal variations used in the development of the alternative plans cost estimation. The quantity of sludge generated as previously described was the basis of design of the sludge handling facilities.

1) Strip Mine Application in Harrison County - The sludges generated in the biological plants were assumed to be digested and pumped to the main transmission lines. The land contractor included the cost of the main transmission lines in his section. Figures 38 and 38A represent the capital cost and operation and maintenance cost for sludge digestion. A 5 percent solids concentration of discharged sludge was assumed. Pumping costs and transmission costs to the main transmission line was based on the data presented in the Unit Cost section. Digestion removal efficiencies were assumed for the different treatment plant schemes based on the mass diagrams. For the conventional activated sludge plant, the dry tons per day discharged from the digester was 53% of the TPD of sludge generated by the plant. For the advanced biological treatment plant, Level 1 and 2, the dry tons per day discharged was 64% of the TPD of sludge generated by the plant.

2) In-basin Agricultural Application - The sludges generated in the

biological treatment plants were digested and vacuum filtered. The land treatment contractor included the cost of picking up the filter cake and applying it to the land in his section. Figures 39 and 39A represent the capital cost and operation and maintenance cost for sludge digestion and vacuum filtration. A 20 percent solids concentration was assumed for the filter cake. Different removal efficiencies were assumed for the different treatment plant schemes based on the mass diagrams. For the conventional activated sludge plant the dry tons per day of solids discharged from the vacuum filter was 60% of the TPD generated by the plant. For the advanced biological treatment plant (Levels 1 and 2), the dry tons per day discharged from the vacuum filter was 64% of the TPD generated by the plant.

3) Incineration - This process includes thickening of the waste activated sludge, storage of the combined sludges, heat treatment, vacuum filtration, and incineration. Figures 40 and 40A represent the capital cost and operation and maintenance cost for this incineration scheme. Only sludge generated in the advanced biological treatment plant was incinerated. The resultant dry tons per day on ash was 35% of the dry tons per day of sludge generated by the plant.

4) Ash Disposal - This sludge handling technique disposes of the waste ash from the incinerators in a sanitary landfill. The cost used for this technique was $6 per dry ton of ash. This cost was used for the disposal of the waste ash from the recalcination furnace and for the disposal of the ash from the incineration disposal scheme.

4.3 Cost Comparison

Tables 4 and 5 present the component costs for the advanced

biological treatment plants and the physical-chemical treatment plants at Level 2. The tables show the costs used in the Chicago Regional study versus that used in the Cleveland Regional study.

TABLE 4

ADVANCED BIOLOGICAL TREATMENT PLANT (LEVEL 2)

	Chicago[1]		Cleveland	
	Capital[2] $1000/mgd	O&M $/MG	Capital $1000/mgd	O&M $/MG
Primary and Secondary	367	60	420	76
Phosphorus Removal[3]	118	50	10	45
Nitrification & Denitrification	136	35	106	38
Mixed Media Filtration	49	15	47	18
Carbon Adsorption	165	68	175	45
Post Aeration	6	10	12	10
Chlorination	4	4	10	8
TOTAL	845	242	780	240
Chicago Plant with Phosphorus removal used in Cleveland Plant	737	237	780	240

1.) Reference: Regional Wastewater Management Systems for the Chicago Metropolitan Area, Technical Appendix, Office of the Chief of Engineers, Department of the Army, March, 1972.

2.) Capital Costs from the Reference were adjusted from an ENR of 1850 to 1740.

3.) The Chicago report used a tertiary process for phosphorus removal whereas the Cleveland report incorporated phosphorus removal into the secondary plant.

TABLE 5

PHYSICAL-CHEMICAL TREATMENT PLANT (LEVEL 2)

	Chicago[1]		Cleveland	
	Capital[2] $1000/mgd	O&M $/MG	Capital $1000/mgd	O&M $/MG
Phosphorus Removal[3]	118	50	110	82
Carbon Adsorption	165	68	175	45
Mixed Media Filtration	49	15	47	18
Post Aeration	6	10	-	-
Ammonia Removal	150	72	-	-
Chlorination	4	4	-	-
Downflow Carbon	-	-	83	23
Breakpoint Chlorination	-	-	10	47
Ozonation	-	-	34	31
TOTAL	492	219	459	246

1.) See Note 1, Table 4.

2.) See Note 2, Table 4.

3.) Same as Coagulation and Sedimentation in the Cleveland Study.

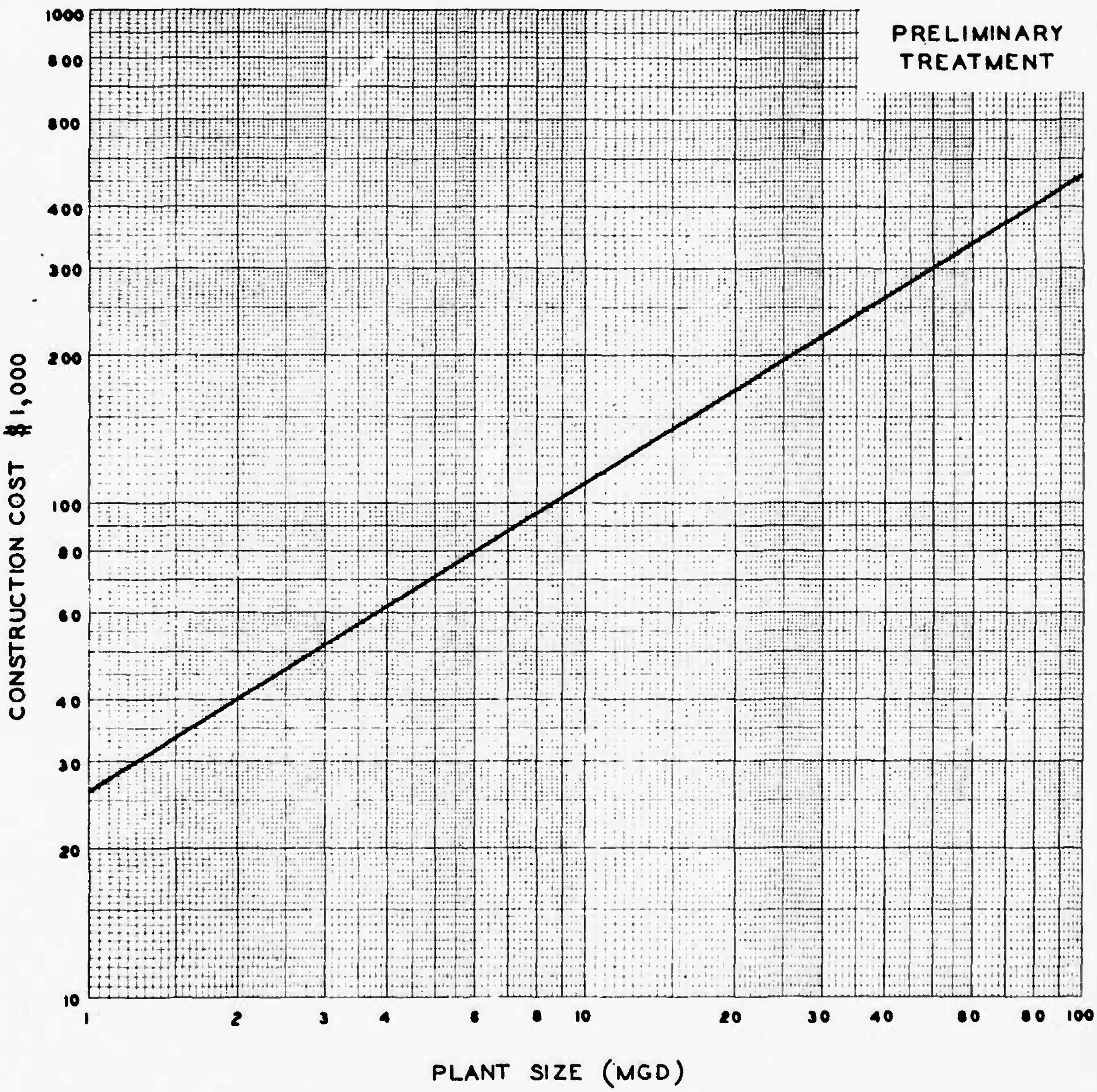

PRELIMINARY
TREATMENT
CONSTRUCTION COST $1,000
1000
800
600
400
300
200
100
80
60
40
30
20
10
1
2
3
4
6
8
10
20
30
40
60
80
100
PLANT SIZE (MGD)

Figure No. 33

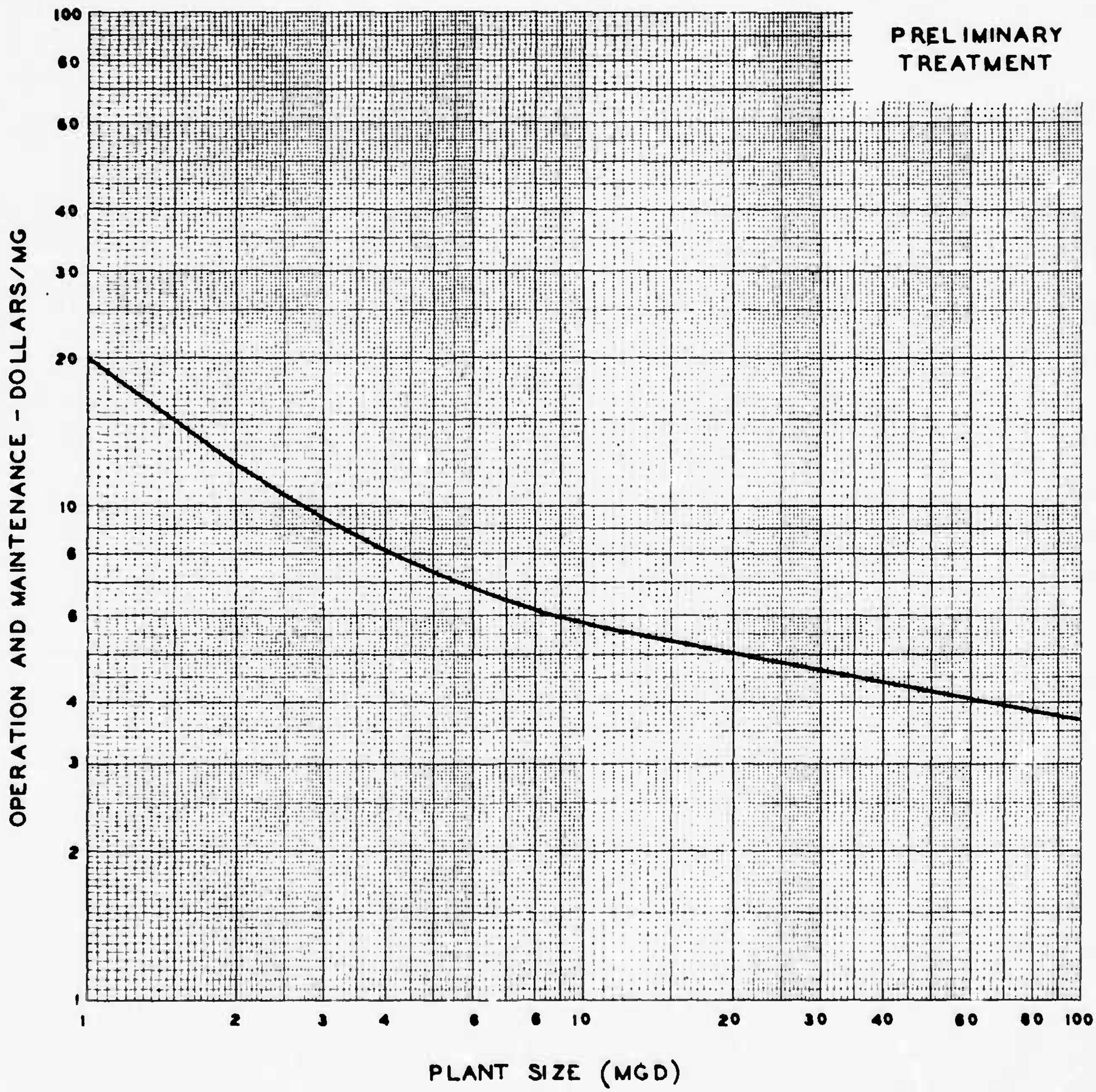


Figure No. 33A

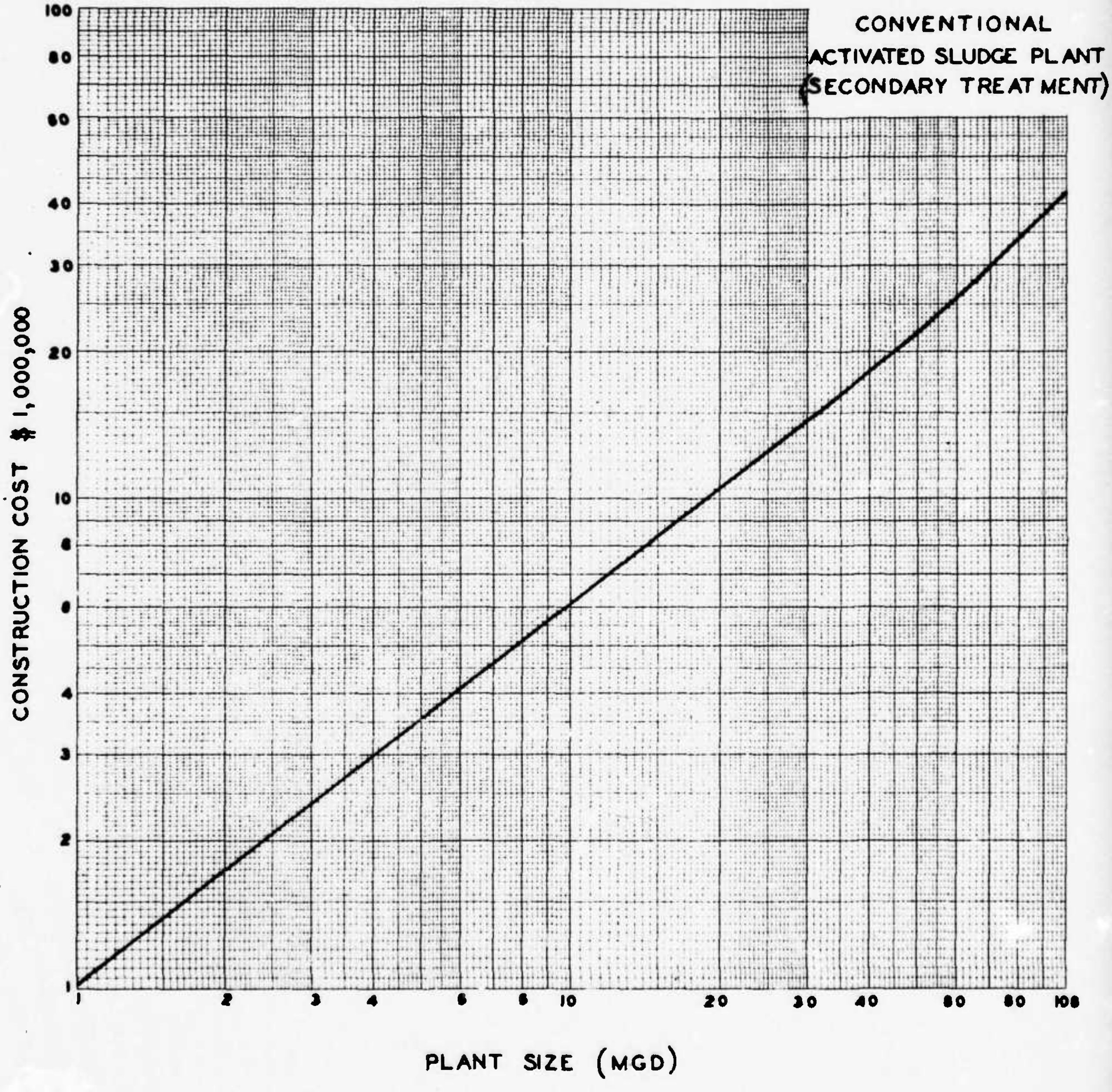

CONVENTIONAL
ACTIVATED SLUDGE PLANT
(SECONDARY TREATMENT)
CONSTRUCTION COST $ 1,000,000
PLANT SIZE (MGD)
100
80
60
40
30
20
10
8
6
4
3
2
1
1
2
3
4
6
8
10
20
30
40
60
80
100

Figure No. 34

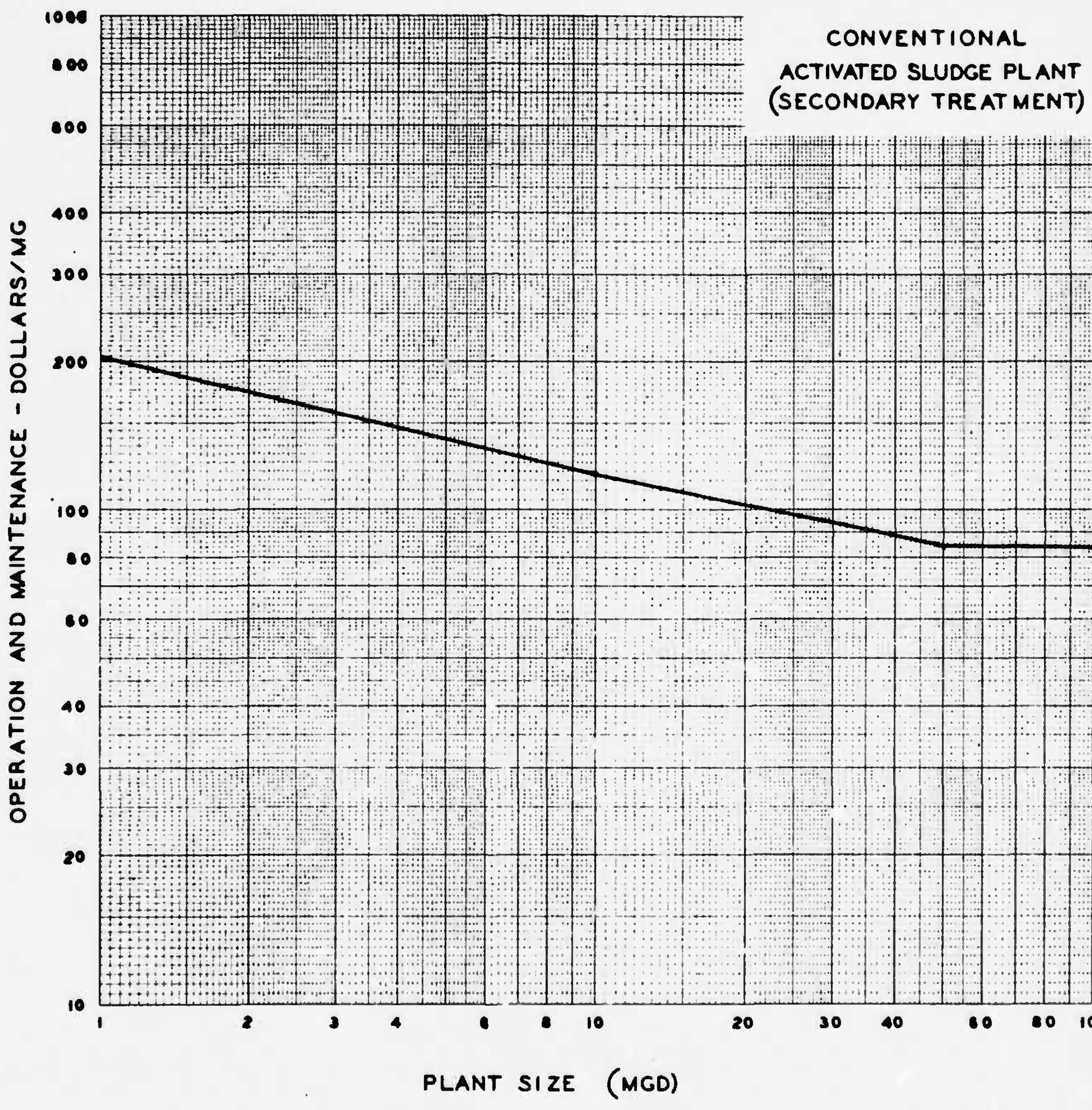


Figure No. 34A

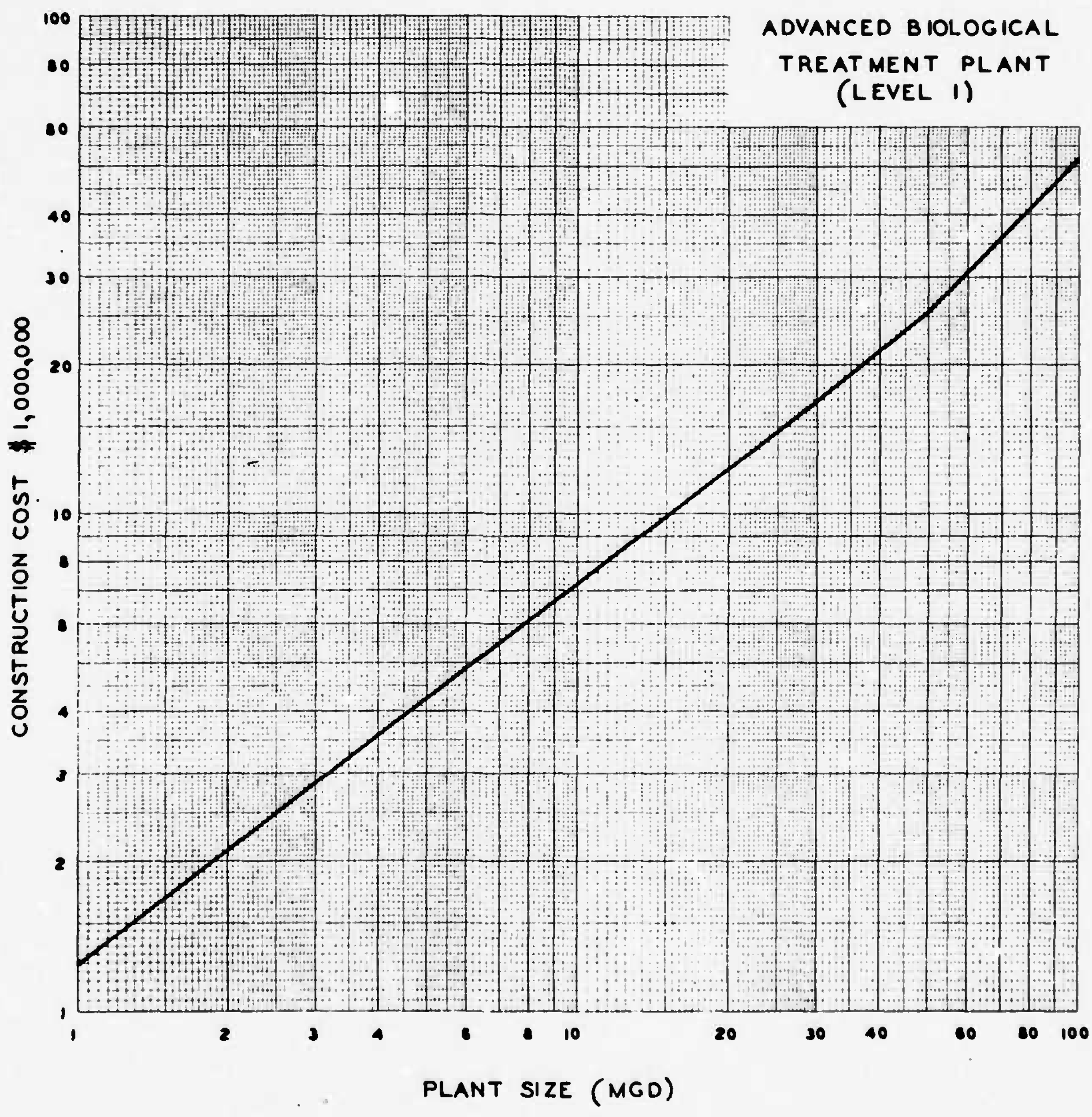

ADVANCED BIOLOGICAL TREATMENT PLANT (LEVEL 1)
CONSTRUCTION COST $ 1,000,000
PLANT SIZE (MGD)
1
2
3
4
6
8
10
20
30
40
60
80
100

Figure No. 35

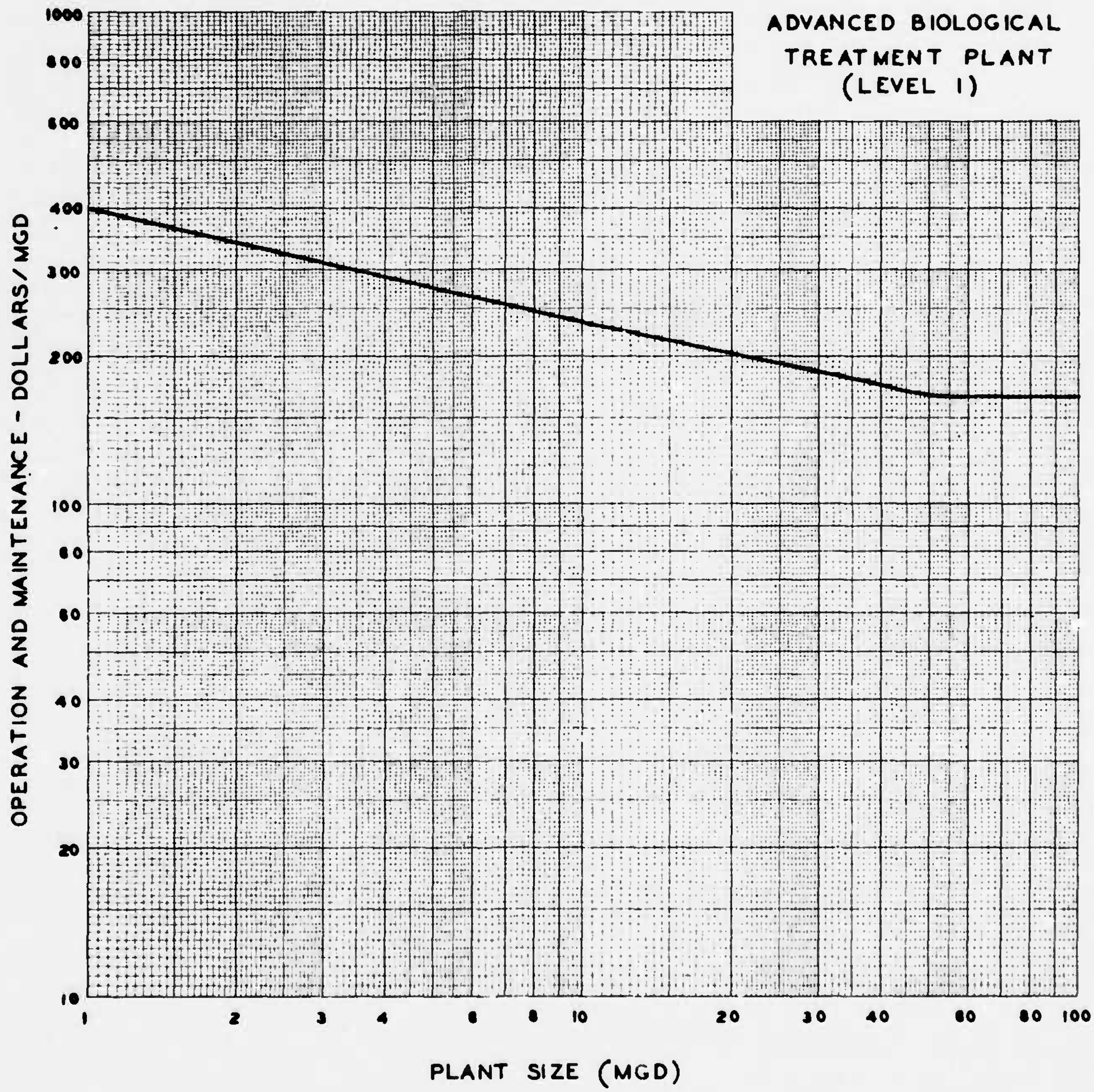


Figure No. 35A

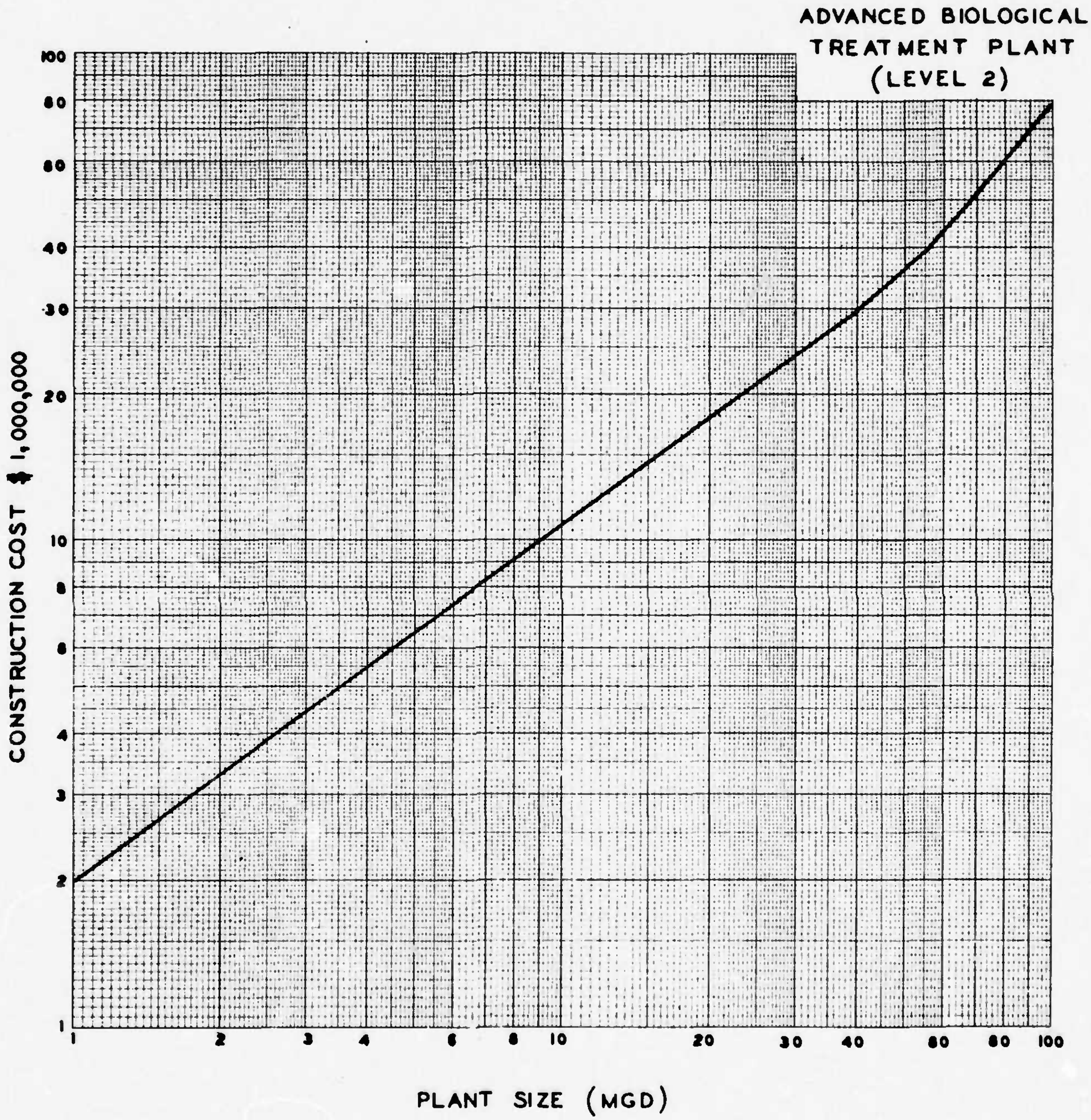

ADVANCED BIOLOGICAL TREATMENT PLANT (LEVEL 2)
CONSTRUCTION COST $ 1,000,000
100
80
60
40
30
20
10
8
6
4
3
2
1
1
2
3
4
6
8
10
20
30
40
60
80
100
PLANT SIZE (MGD)

Figure No. 36

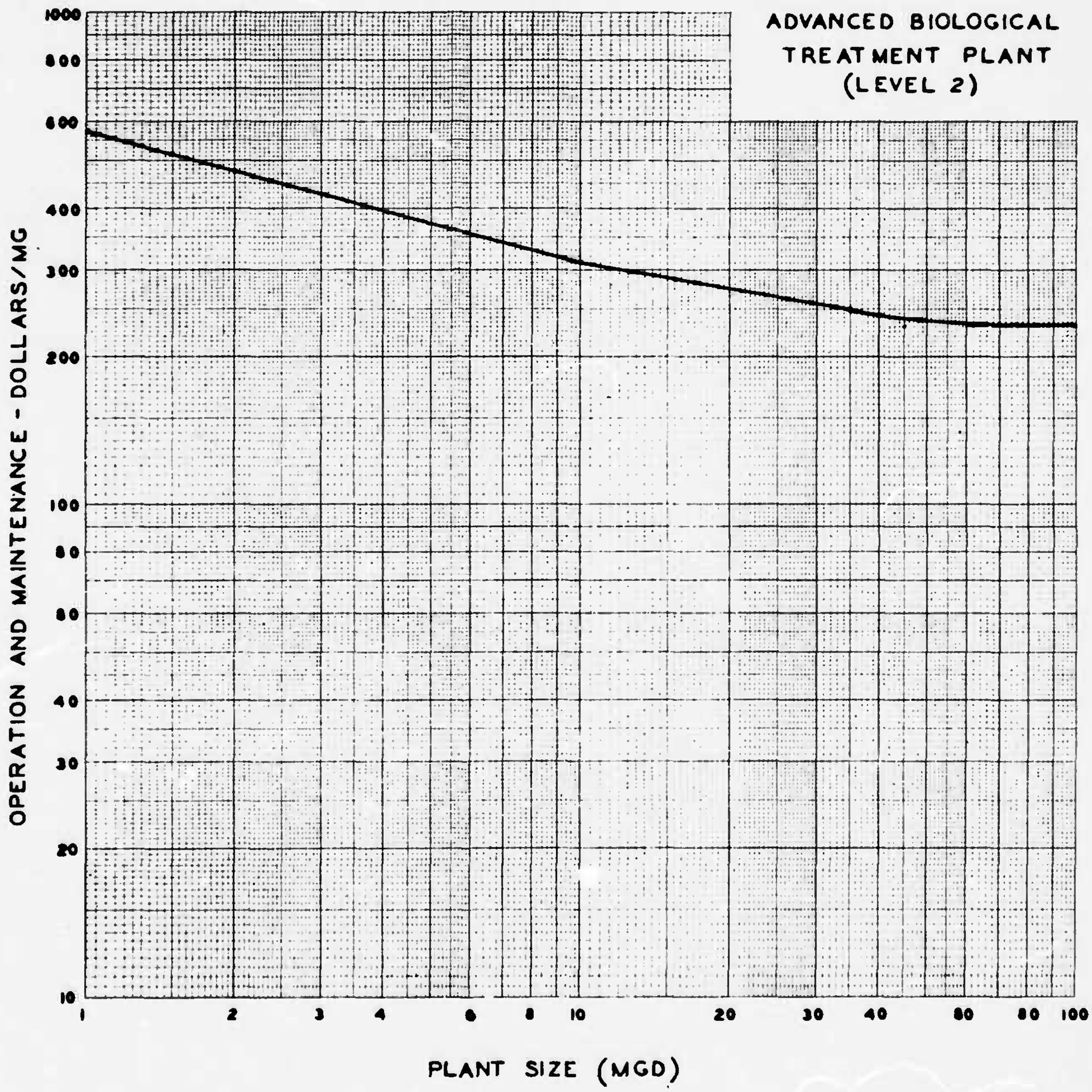


Figure No. 36A

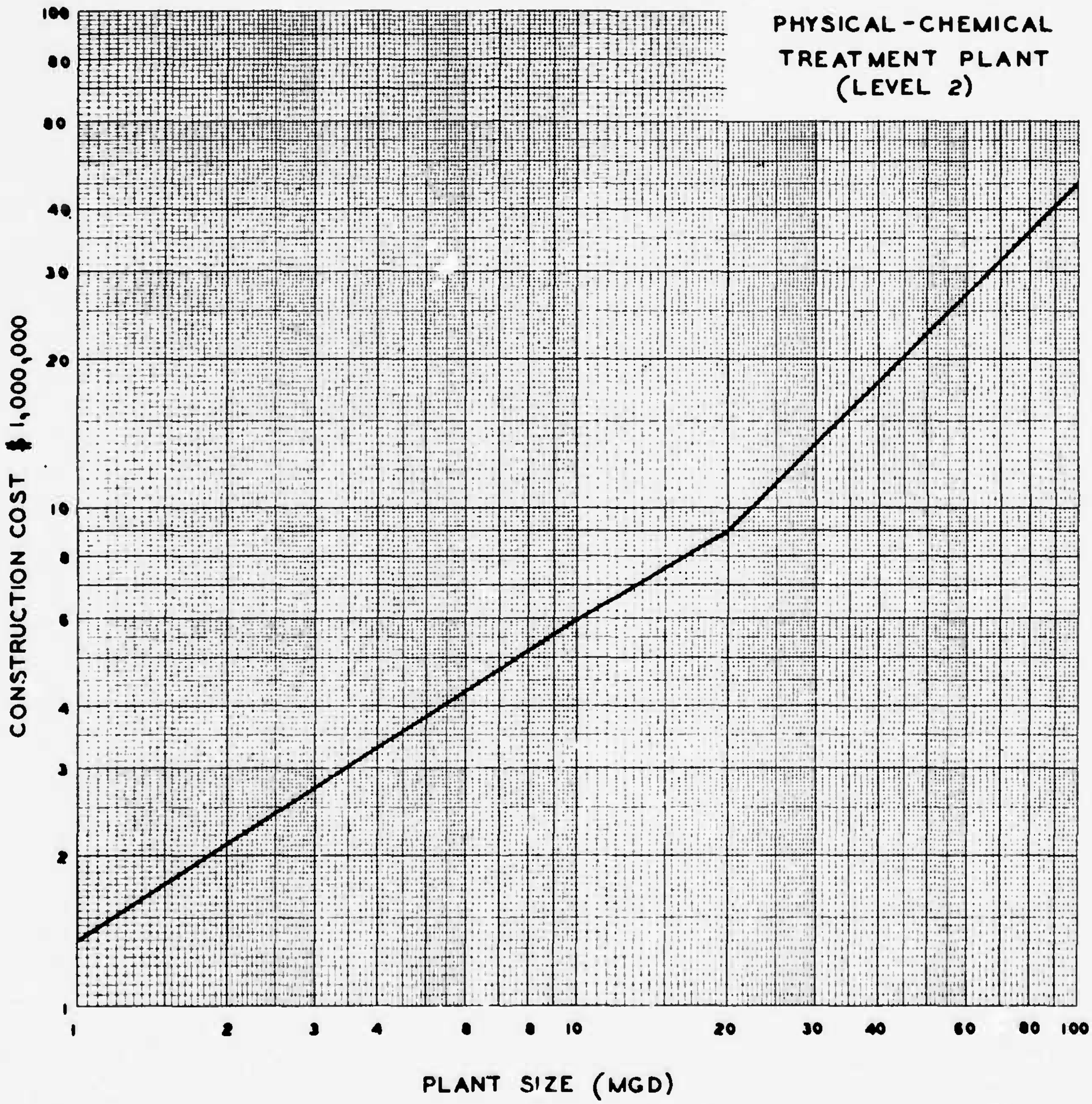

PHYSICAL - CHEMICAL
TREATMENT PLANT
(LEVEL 2)
CONSTRUCTION COST $ 1,000,000
PLANT SIZE (MGD)
1
2
3
4
6
8
10
20
30
40
60
80
100

Figure No. 37

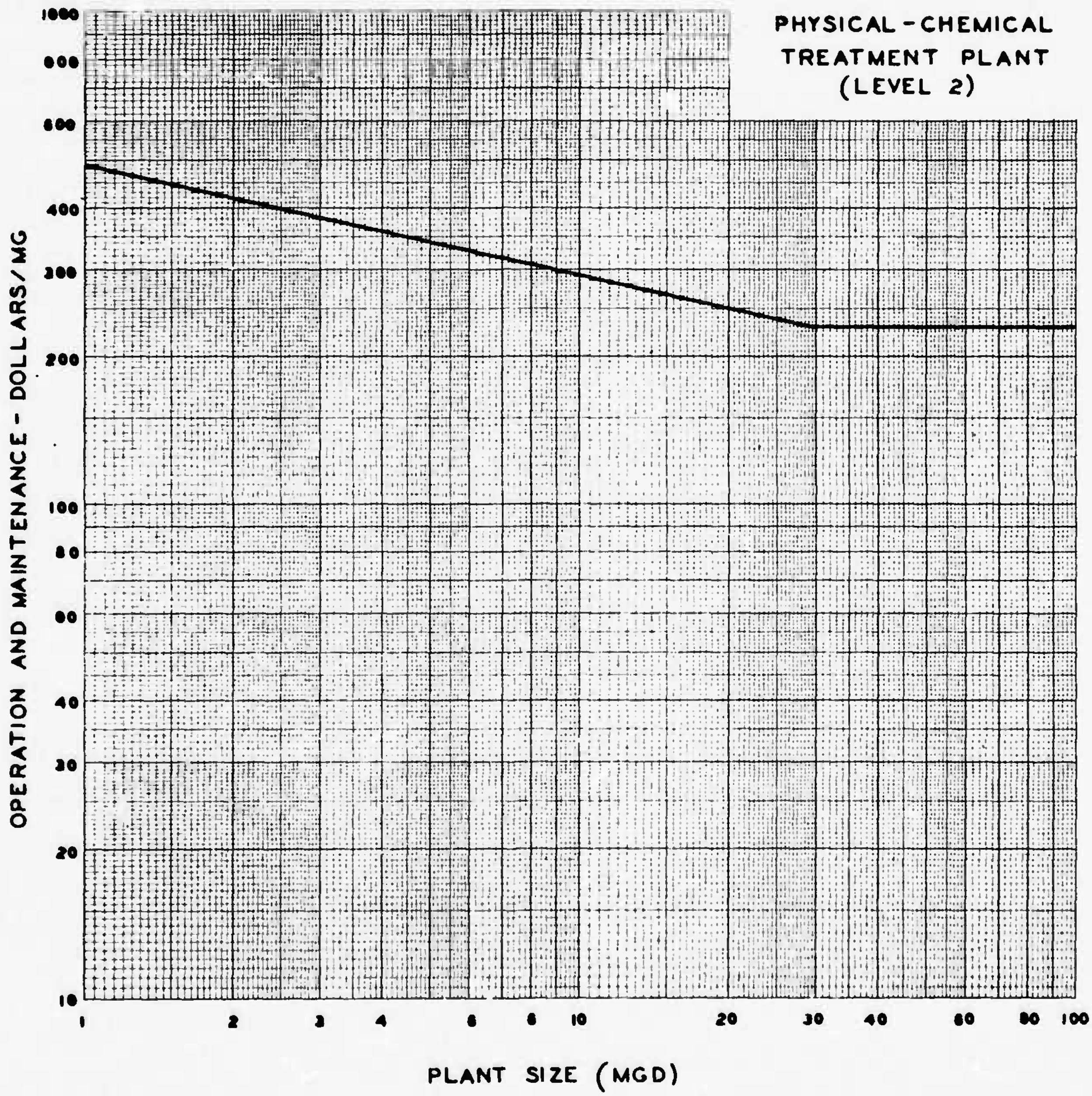


Figure No. 37A

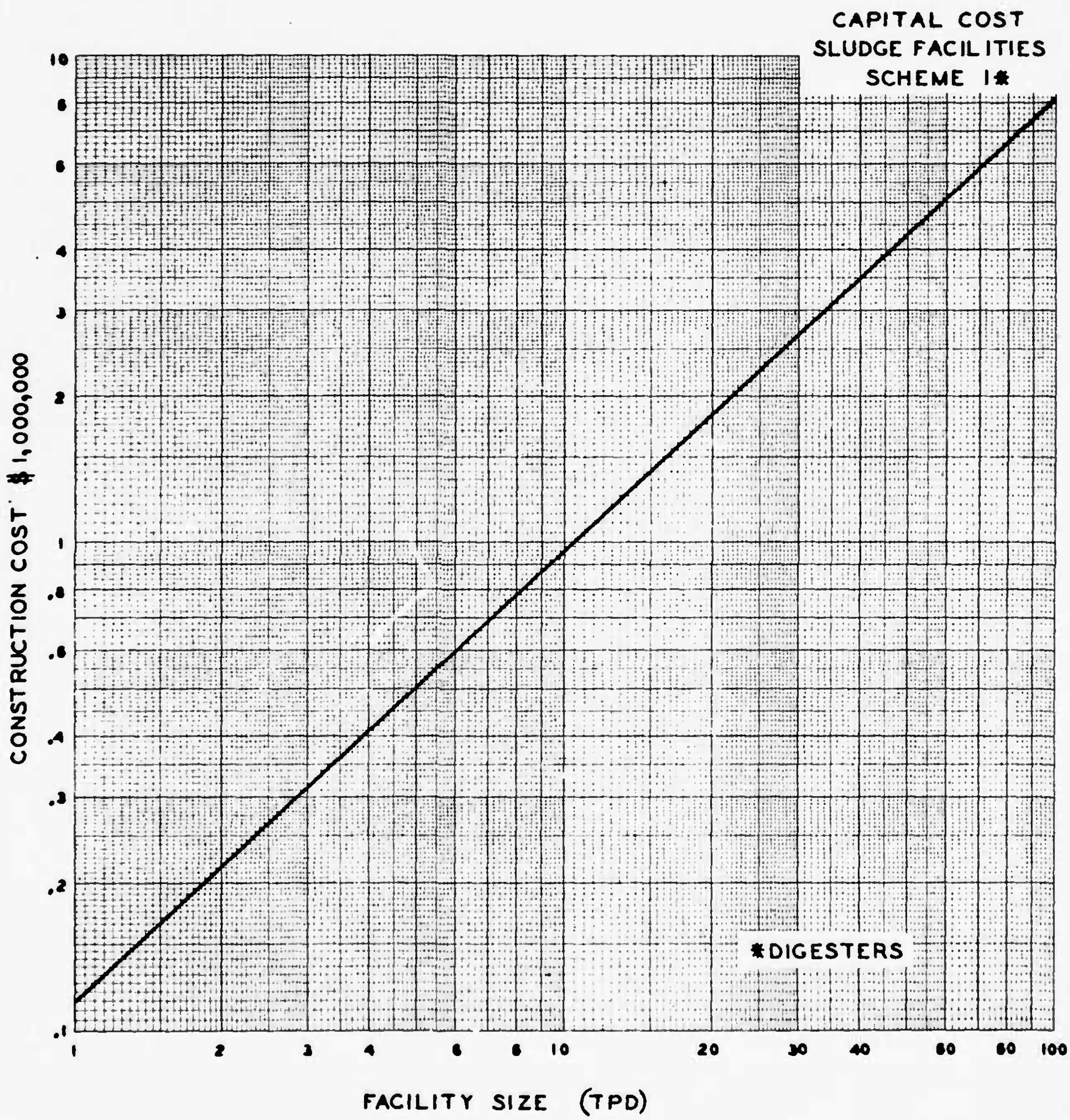

CAPITAL COST
SLUDGE FACILITIES
SCHEME 1*
CONSTRUCTION COST $1,000,000
FACILITY SIZE (TPD)
*DIGESTERS
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
.1
1
2
3
4
6
8
10
20
30
40
60
80
100

Figure No. 38

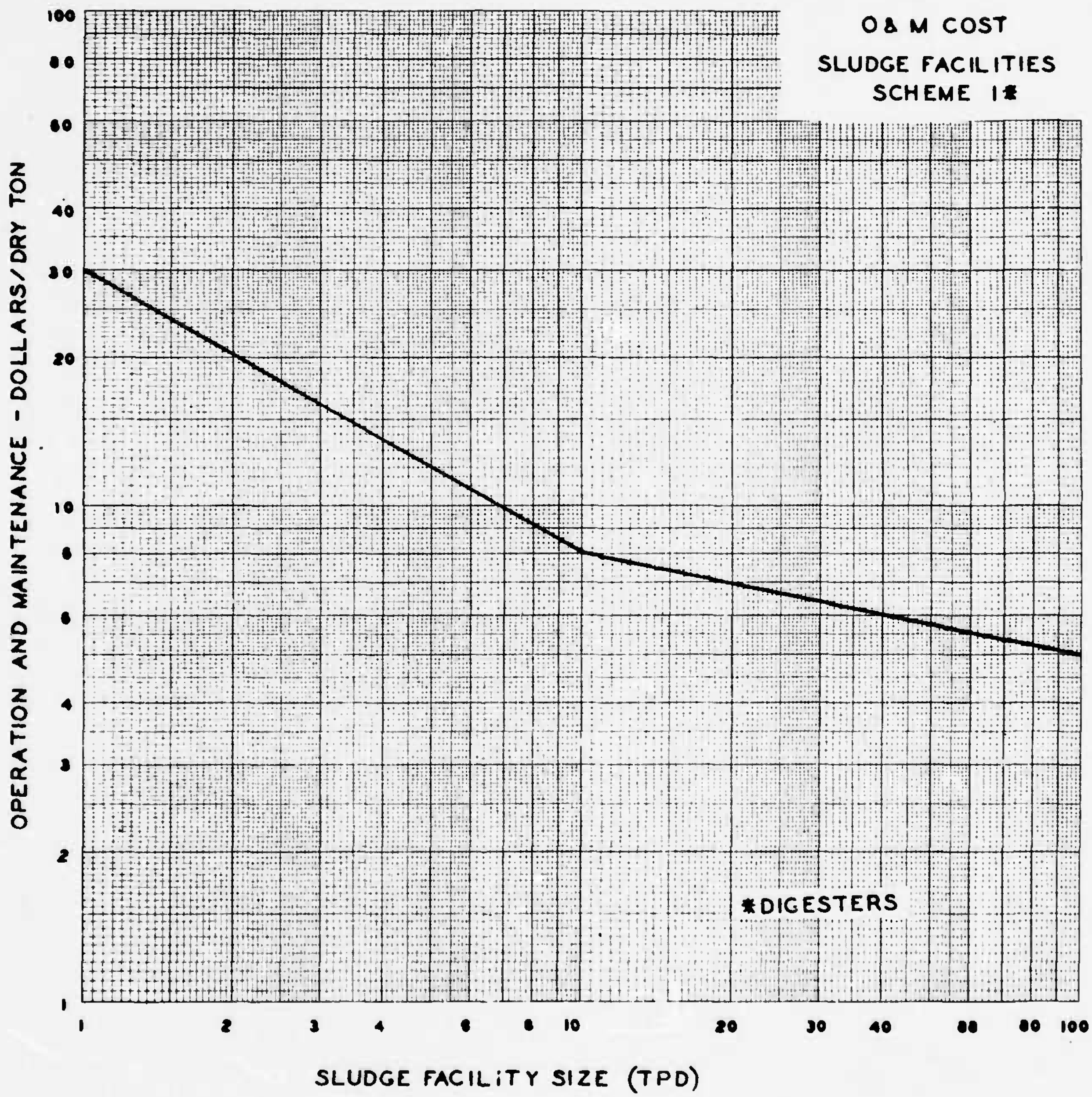


Figure No. 38A

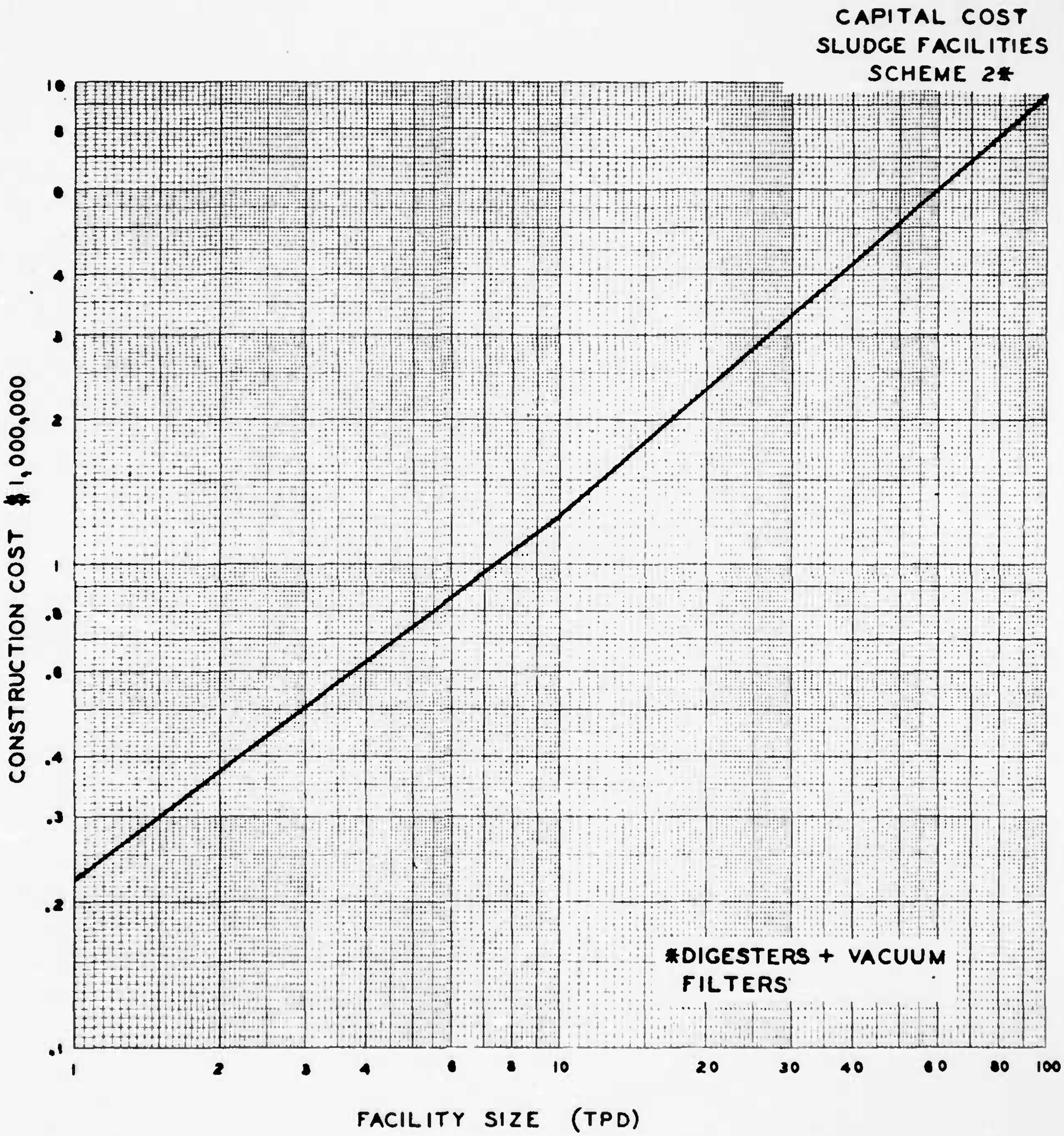

CAPITAL COST
SLUDGE FACILITIES
SCHEME 2*
CONSTRUCTION COST $1,000,000
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
.1
1
2
3
4
6
8
10
20
30
40
60
80
100
*DIGESTERS + VACUUM
FILTERS
FACILITY SIZE (TPD)

Figure No. 39

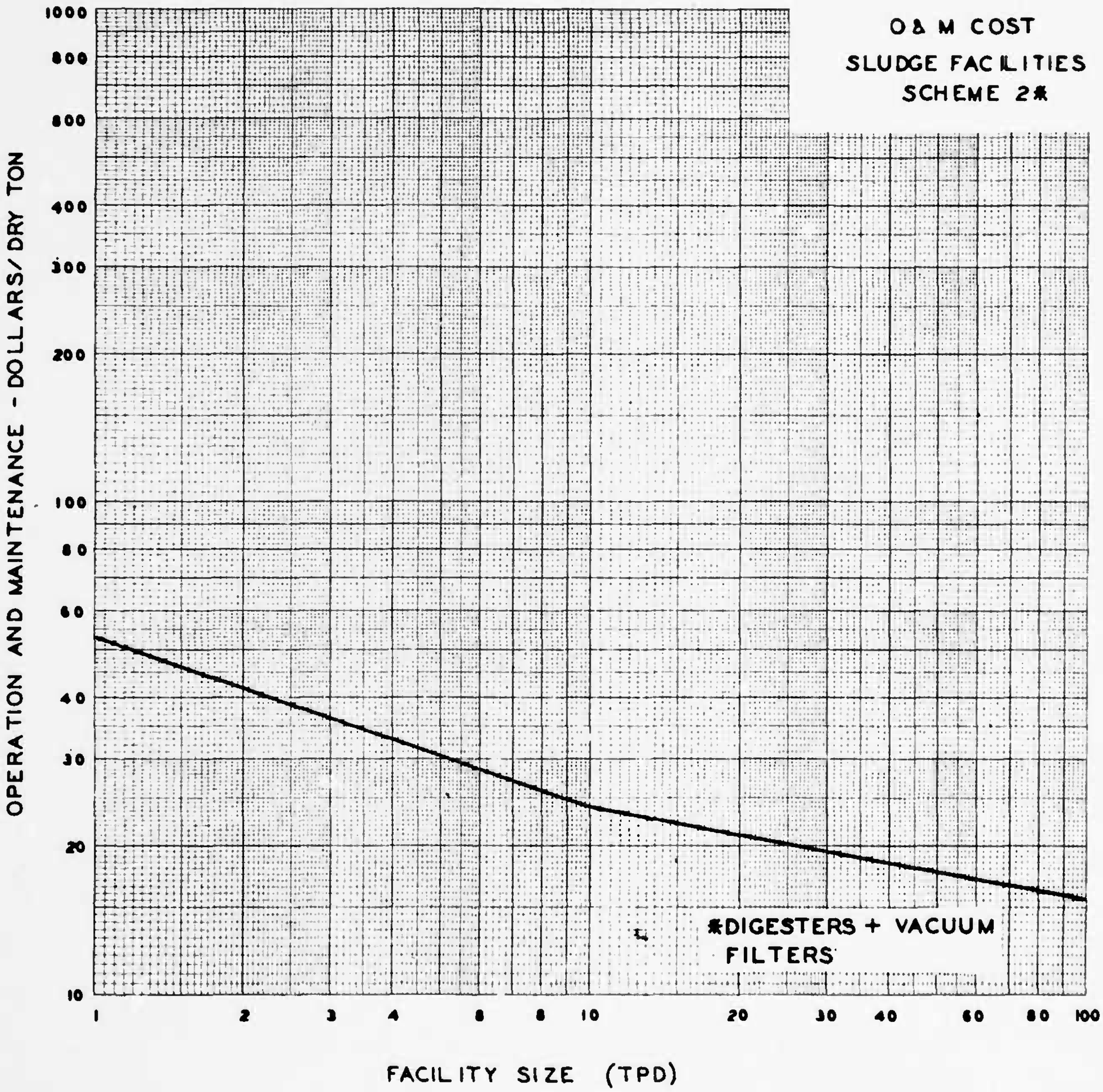


Figure No. 39A

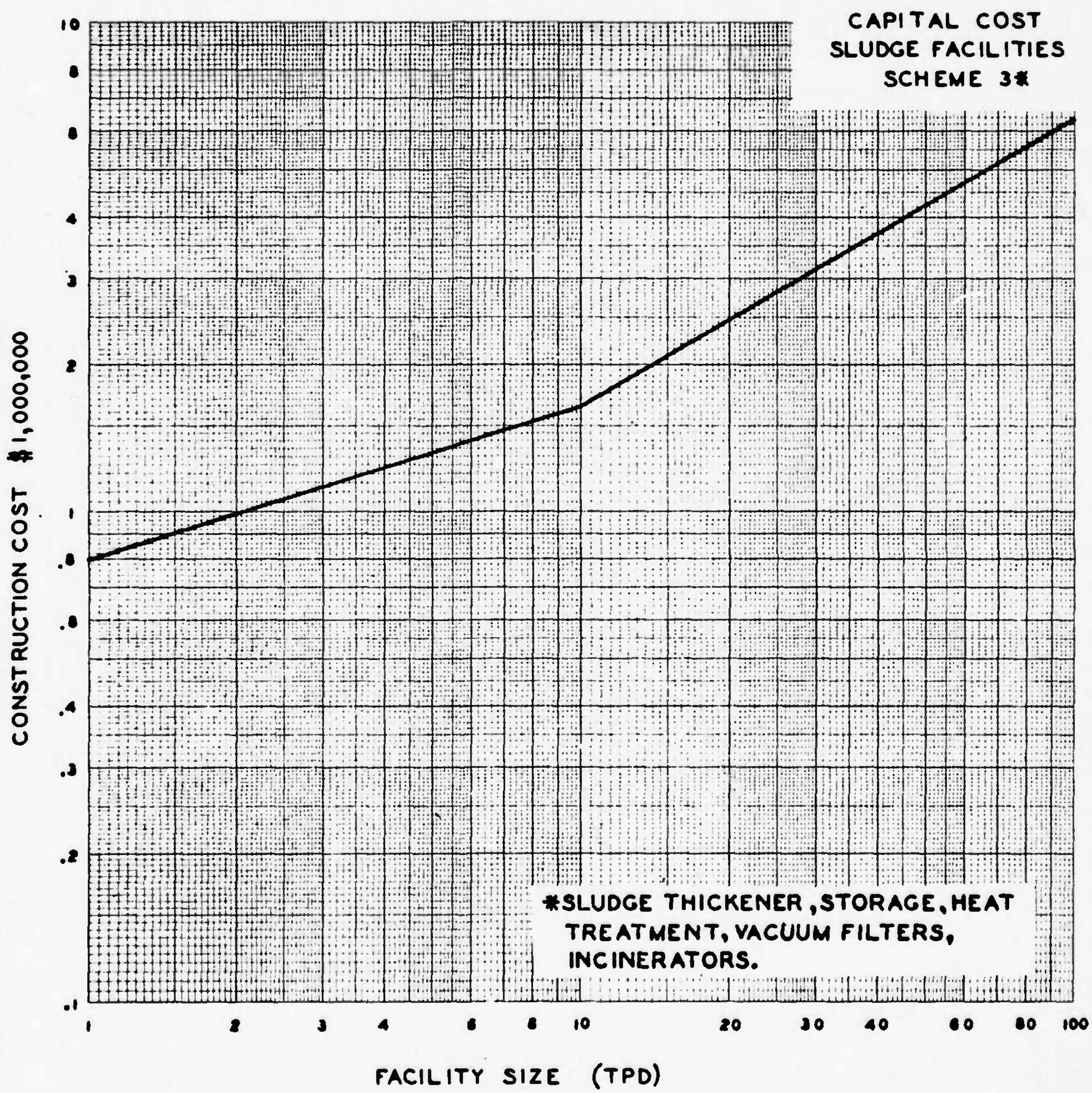

CAPITAL COST
SLUDGE FACILITIES
SCHEME 3*
*SLUDGE THICKENER, STORAGE, HEAT TREATMENT, VACUUM FILTERS, INCINERATORS.
CONSTRUCTION COST $1,000,000
FACILITY SIZE (TPD)
10
8
6
4
3
2
1
.8
.6
.4
.3
.2
.1
1
2
3
4
6
8
10
20
30
40
60
80
100

Figure No. 40

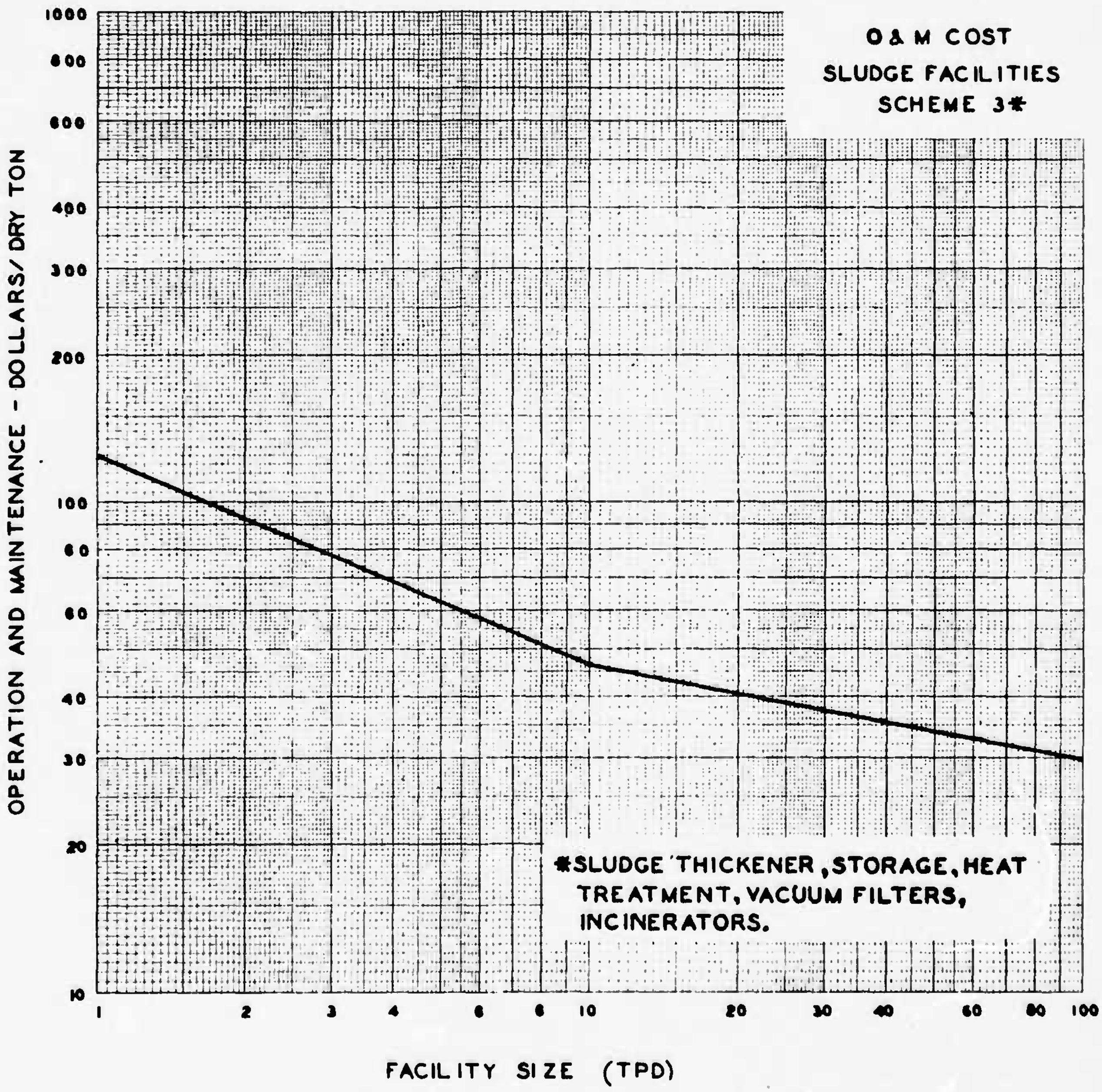


Figure No. 40A

B - STORMWATER RUNOFF

This section of the Phase II report discusses the treatment of urban stormwater runoff as part of the total wastewater management study. The wastewater management goals for stormwater are the same as defined in the wastewater section for the O.C.E. goals; however, for the State goals, screening and sedimentation followed by microstraining and disinfection were established to be adequate. The State or Level 1 stormwater effluent quality criteria is different from wastewater due to the character of the constituents of runoff. A large percentage of the suspended solids in stormwater runoff would be categorized as inert suspended solids for which the State allowable concentrations can be satisfied by the unit processes considered.

1. TREATMENT PROCESSES AND EFFECTIVENESS

Stormwater runoff flows are intermittent and have high peak rates. Quality of storm runoff varies widely during the storm and from one storm to another because of the hydrologic factors involved, such as percentage of imperviousness of the drainage area, rainfall intensities and duration and antecedent rainfall. A feasible treatment process requires a storage basin to reduce the peak rates so that treatment units may be sized for lower rates of flow. It is also economical to utilize the storage basin for sedimentation in order to capture a substantial part of suspended solids, BOD and other pollutants. The storage basin will serve also as a means to mix the stormwater and produce a more homogeneous mixture which approaches the average quality assumed for design.

1.1 PROCESS CONSIDERATIONS

Process considerations for stormwater treatment facilities include the following:

(a) Hydraulic surge control and storage to reduce instantaneous maximum hydraulic rates to treatment;

(b) Capability of providing immediate service at or near maximum efficiency with low degree of operator attention;

(c) Avoidance of substantial inventory in idle capital equipment, i.e., maximize flow dependent operating expenditures;

(d) Self-contained process sequence exclusive of solids disposal.

1.2 STORMWATER RUNOFF TREATMENT SYSTEMS

As a function of the stormwater source, treatment systems and their rationale are presented herein.

1.21 LEVEL 1 - SEPARATE STORMWATER RUNOFF TREATMENT SYSTEM

Figure B1 shows a schematic diagram for separate stormwater treatment to Level 1. The process includes: coarse screening, storage and sedimentation basin (which may be earth or concrete), and a pumping station to pump stormwater from the basin to a microstrainer installation. Disinfection of stormwater by ozonation follows before flow is finally discharged to streams, rivers or Lake Erie. Microstrainer backwash is treated by sedimentation. Earth basins will normally include three cells to provide for periodic sludge removal by bulldozing and trucking or piping to landfills or the central sludge disposal site. Concrete basins will be provided with mechanical sludge collectors, and sludge will be pumped to a central sludge disposal site.

1.22 LEVEL 1 - COMBINED SEWER OVERFLOW TREATMENT SYSTEM

Figure B2 shows a schematic for combined sewer overflows treatment to Level 1. This process is similar to that of Figure B1, described above. The storage sedimentation basin will be concrete with mechanical sludge collectors in all cases. Combined sewer areas are highly urbanized with limited available land, and combined overflows have higher BOD concentration than separate stormwater.

1.23 LEVEL 2 - SEPARATE STORMWATER RUNOFF TREATMENT SYSTEM

Treatment of separate stormwater largely reduces to one of particulate solids control and disinfection. However, to meet the proposed Federal effluent BOD_5 and COD standard, soluble organic removal must be provided. The proposed treatment sequence is schematically shown in Figure B3*with its performance illustrated in Figure B3A*.

The pretreatment, and storage and sedimentation tank are the same as contained in the systems designed to meet the proposed State effluent standards. Sequentially, in the flash mix and flocculation facilities, powdered activated carbon, alum, and polymer are added in flow dependent dosages. The powdered activated carbon (with a cost of about 1/3 the granular activated carbon) is applied to remove the majority of soluble organics; its use was selected to minimize the idle granular activated carbon inventory and minimize the required carbon contacting time in the subsequent downstream filtration process. Alum is added as a primary coagulant. Some precipitation of soluble phase phosphorus would be predicted. The organic polymer is applied as a secondary coagulant for its floc building and strengthening properties. The long detention time and low surface overflow rate of the storage/sedimentation tank should result in an effluent with low suspended solids.

The downflow dual media granular activated carbon-sand filter will provide further soluble organic removal with effluent suspended solids residuals at a point acceptable to the proposed Federal effluent standards. Backwashing will most likely not be required during stormwater treatment and will normally be conducted following a storm with an ozonated backwash stream to remove accumulated solids and "sterilize" the bed so that bacterial activity is at a minimum during idle conditions. An alternative to this mode of operation would be to aerate the carbon bed during idle operation to promote bacterial removal of the adsorbed organics, and thus, achieve some microbial regeneration of the carbon. Spent or exhausted carbon is to be trucked and regenerated at

*Federal Goals refer to standards established by O.C.E. (Office of the Chief of Engineers).

the furnaces contained at the regional wastewater treatment plant.

Ozonation is provided for disinfection and final organic polishing or removal prior to discharge into the receiving body of water.

1.24 LEVEL 2 - COMBINED SEWER OVERFLOW TREATMENT SYSTEM

Combined sewer overflow treatment presents the same technical problems as municipal wastewater treatment except that it is somewhat more dilute. System hydraulic loads vary rapidly from zero to peak rate as influenced by the storm intensity and runoff characteristics of the service area. Rather than substantially oversize the main wastewater treatment facility, a treatment facility that could complement or operate at an isolated location is proposed. Such a system is shown schematically in Figure B4 with its performance illustrated in Figure B4A. In situations where the combined sewer overflow treatment system is contained on the same physical site as the municipal wastewater treatment plant, the latter would be operated at its peak capacity during the storm with the stormwater treatment installation to reduce costs.

As shown in Figures B4* and B4A*, the only additional unit process for this treatment system as compared to the sequence proposed for separate stormwater runoff is breakpoint chlorination for nitrogen removal. Excluding the polymer application, powdered activated carbon and alum dosages have been increased for higher organic and phosphorus removal, respectively. A lower polymer application is possible because of the higher dosage of alum for phosphorus precipitation. Lime addition in both the flocculation and breakpoint chlorination systems is for alkalinity control. The granular activated carbon filter follows breakpoint chlorination to remove any chlorinated hydrocarbons that may have been formed during breakpoint; no real organic removal is assumed to result with this operation.

*Federal Goals refer to standards established by O.C.E. (Office of the Chief of Engineers).

1.25 LEVEL 1 and LEVEL 2 - SEPARATE OR COMBINED SEWER RUNOFF TREATED IN MUNICIPAL PLANTS

As discussed in the wastewater design criteria section, the unit processes are designed to treat flows greater than average. During the course of a day, the sanitary flow will fluctuate from a minimum which usually occurs in the early morning hours to a maximum which usually occurs at mid-day. Likewise, the flow in the sewers fluctuates by similar cycle. Under the concept of treating storm or combined sewer runoff in a municipal plant, the runoff water would be stored in storage basins and discharged into the sewer systems and carried to the plant during the hours of low flow.

Storage under this scheme becomes a significant cost because of the volume of runoff water to be treated. The rate at which this can be released into the municipal system is a function of the plant size. The question is how much storm water or combined overflow can be taken through the plant without upsetting the pollutant mass loading and decreasing the efficiency of the process? The control of the release would have to be routed such that the release from storage would not increase the flow above the peak design sanitary flow. The system would have to be flow monitored at several locations along the pipeline as well as at the plant itself. In systems with several storage basins releasing stored water, the system would undoubtedly have to be controlled by on-system-mini-computers and automatically controlled gates and variable speed pumps. The maximum rate of release is also a function of plant size as indicated below.

Plant Size as Defined by ADF MGD	Ratios		
	$\frac{Q\ MF}{Q\ ADF}$	$\frac{Q\ MDF}{Q\ ADF}$	$\frac{Q\ MF}{Q\ MDF}$
0- 5	3.00	1.5	2.0
5-10	2.85	1.5	1.9
10-15	2.70	1.5	1.8
15-20	2.55	1.5	1.7
20-25	2.40	1.5	1.6
Greater than 25	2.25	1.5	1.5

To compute the maximum flow that can be released, the following procedure was used:

Example: 100 mgd advanced biological plant.

ADF	= 100 mgd	
Max. Flow	= 225 mgd	
Max. Daily Flow	= 150 mgd	
Maximum Allowable Stormwater Release		225 - 150 = 75 mgd
Average Daily Flow with Stormwater		100 + 75 = 175 mgd

Several units within the treatment scheme must be enlarged to treat this increased flow. The increase in cost necessary to enlarge the unit processes is approximately a one-third increase in construction cost over the plant sized for the municipal average daily flow. The unit processes would remain the same. Operation and maintenance cost for the additional flow is the same as for domestic flow.

This particular scheme has several technical difficulties. First, it has not been attempted in plants with flows of this magnitude. Consequently, there is an unknown with regards to the efficiency of operation. Second, if storm water runoff does not need the same degree of treatment, there would be no way of separating the combined flows. Third, the expense of storm water collection and storage may make the construction of the system economically difficult and require a phasing of wastewater followed by stormwater at a later date. Fourth, the diversion of the water downstream to regional plants will reduce the flow in several reaches of streams and may completely dry up some small tributaries.

Consequently, the use of this technique in Phase III will require detailed consideration of a location and type of storage basin, size of wastewater treatment plant, and capacity and condition of existing sewer system.

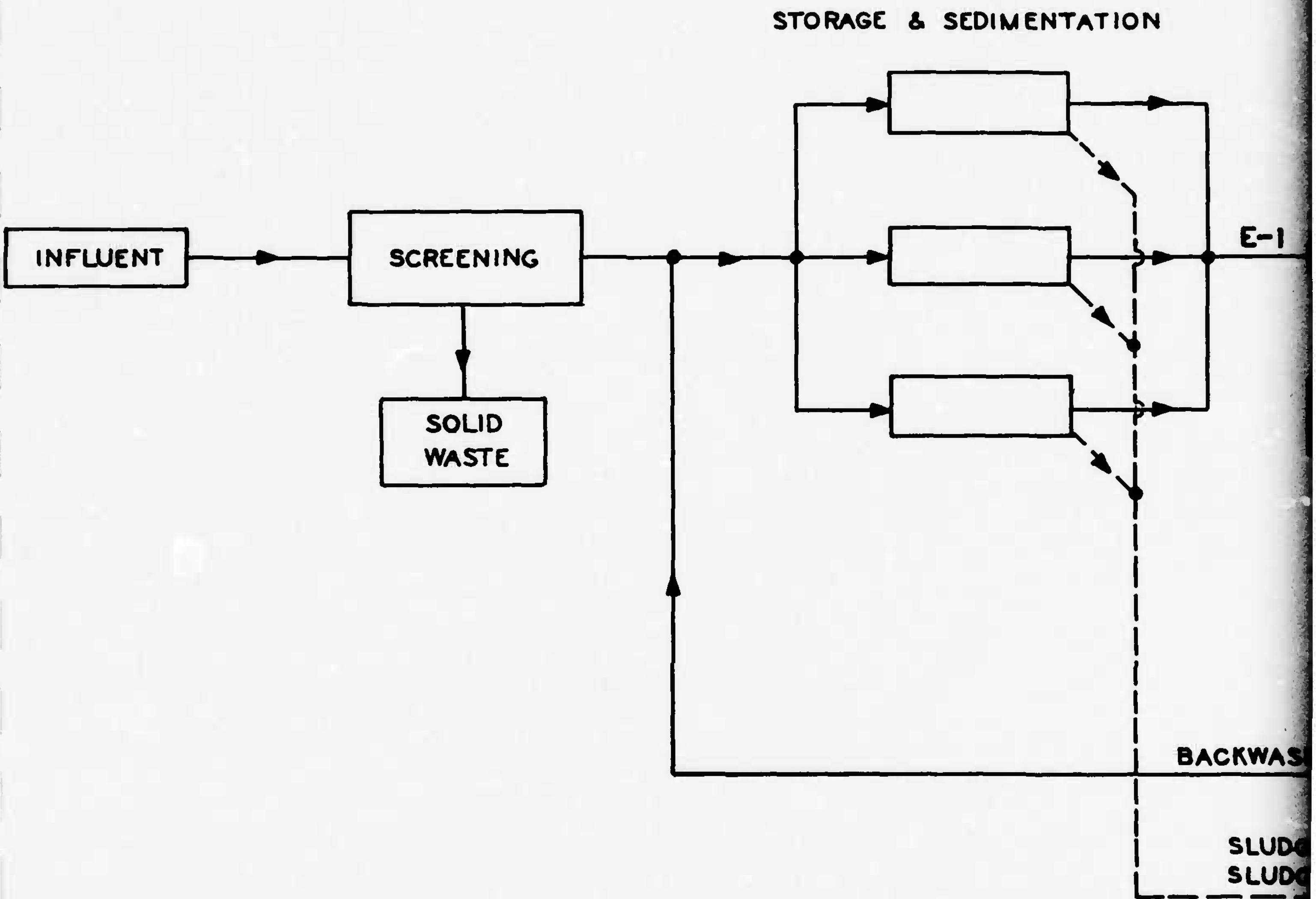
Table B1 presents the alternatives in condensed form.

TABLE B1

STORMWATER RUNOFF TREATMENT

ALTERNATIVES

STORM		COMBINED	
Level 1	Level 2	Level 1	Level 2
a) 2 hour detention, concrete w/sludge collection & micro-straining plus disinfection	a) 2 hour detention, concrete w/sludge collection & advanced stormwater treatment plant	a) 2 hour detention storage in concrete tank w/sludge collection followed by micro-straining and disinfection	a) 2 hour detention storage in concrete tanks w/sludge collection followed by advanced stormwater treatment plant
b) 1 year storm storage 3 day release, earth w/o sludge collection microstraining and disinfection	b) 1 year storm storage 3 day release, earth w/o sludge collection advanced stormwater treatment plant	b) 2 hour detention concrete w/o sludge collection but solids suspension and pump to plant	b) 2 hour detention, concrete w/o sludge collection but solids suspension and pump to plant
c) 30-day storage earth and pump to plant	c) 30-day storage earth and pump to plant		
	d) 30-day storage earth microstraining and disinfection and pump to land		



STORM WATER

CONSTIT-UENT	INFLUENT mg/L	E-1		E-2	
		mg/L	%REMOVAL	mg/L	%REMOVAL
S.S.	500	150	70	50	90
B.O.D.	30	18	40	10	67

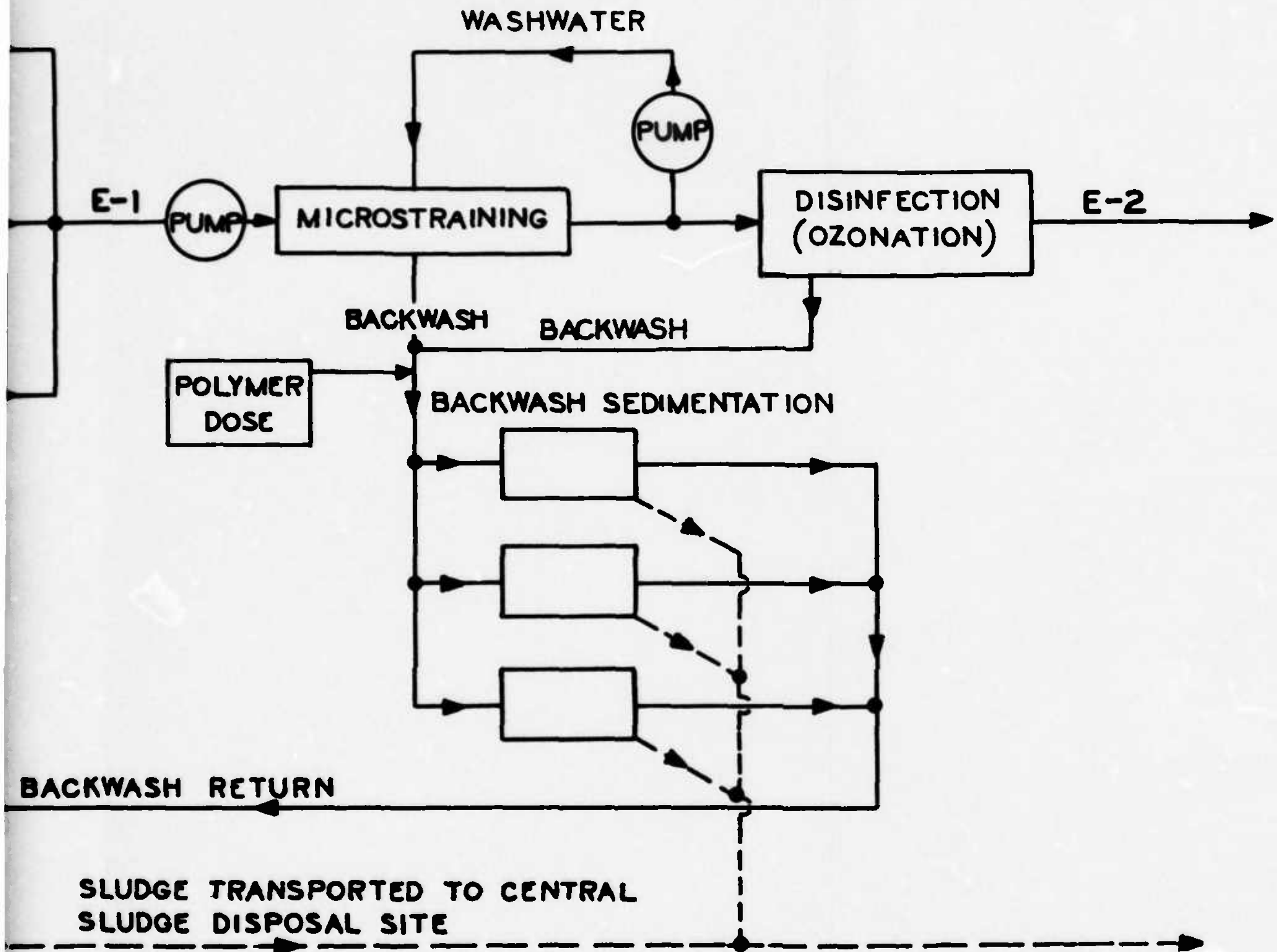
SLUDGE GENERATED

1 — IN STORAGE & SEDIMENTATION

2— IN BACKWASH SEDIMENTATIO

/

HAVENS AND EMERSON, LIMITED



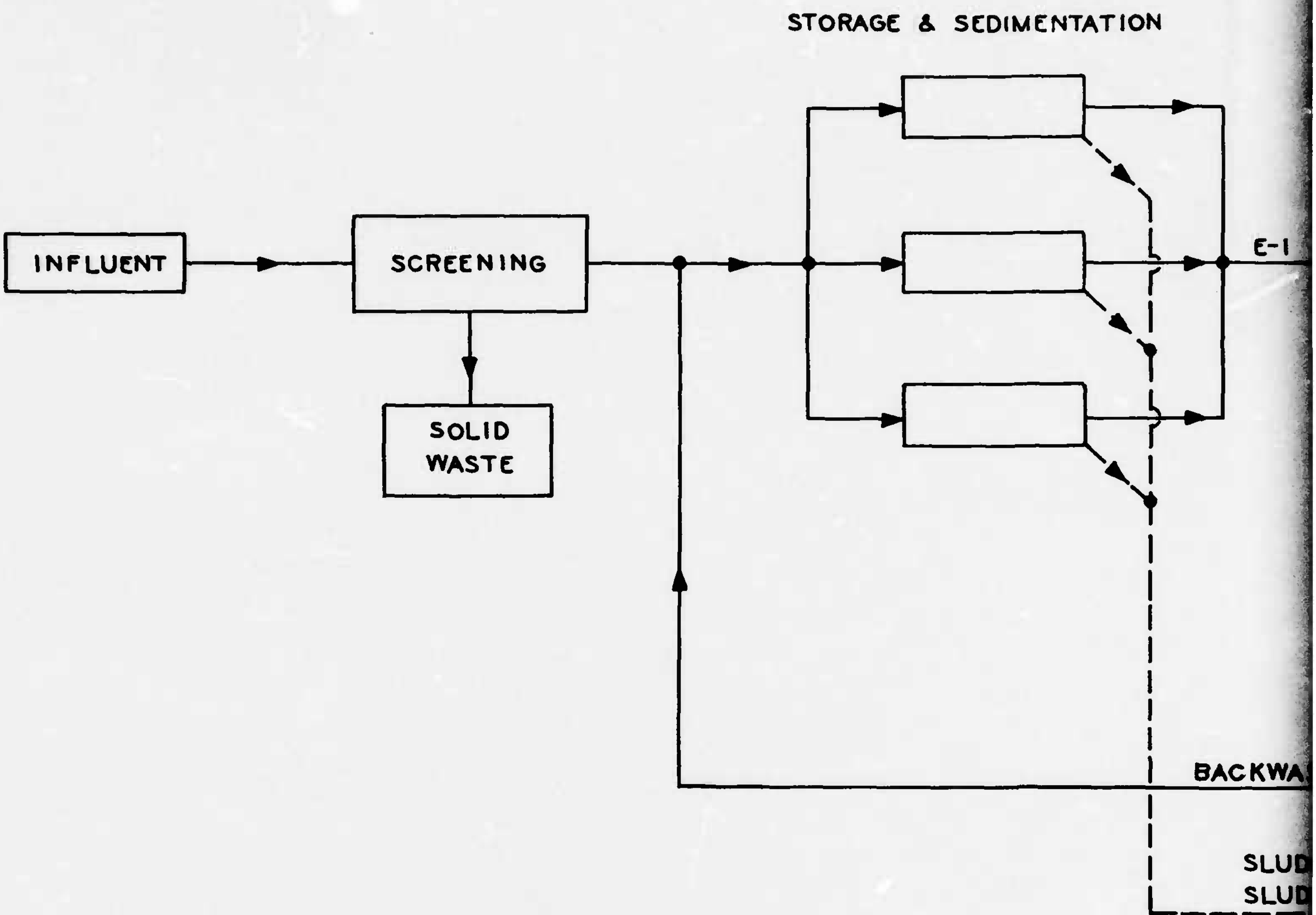
ENTATION BASIN = 6,000 GAL./M.G. OF STORM WATER

MENTATION = 1,500 GAL. M.G. OF STORM WATER

2

FIGURE B1

TREATMENT SYSTEM FOR STORM WATER TO MEET STATE GOALS



COMBINED SEWER OVERFLOWS

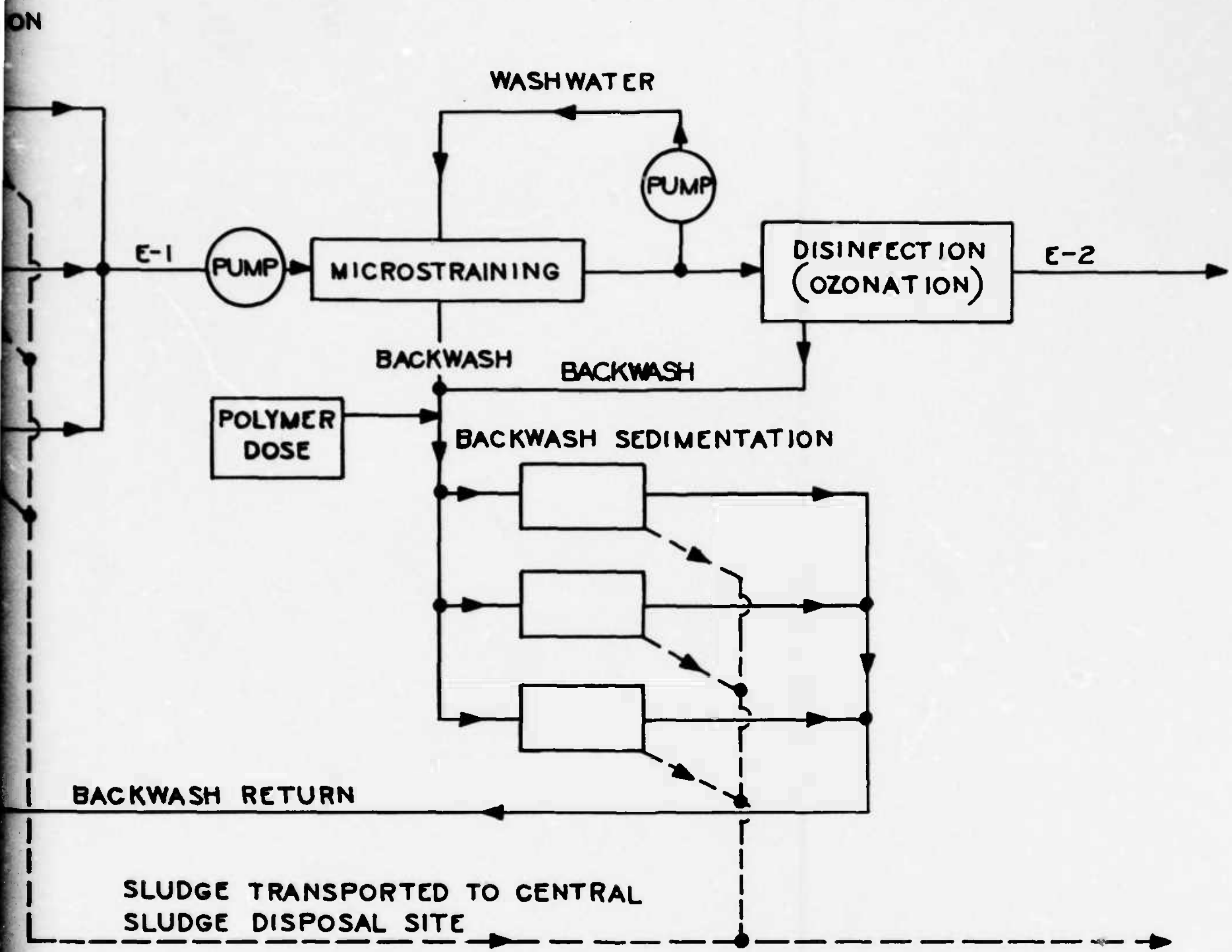
CONSTIT-UENT	INFLUENT mg/L	E-1		E-2	
		mg/L	% REMOVAL	mg/L	% REMOVAL
S S	200	60	70	30	85
B.O.D	60	36	40	10	83

SLUDGE GENERATED

1 – IN STORAGE & SEDIMENTATIO
2 – IN BACKWASH SEDIMENTATION

/

HAVENS AND EMERSON, LIMITED

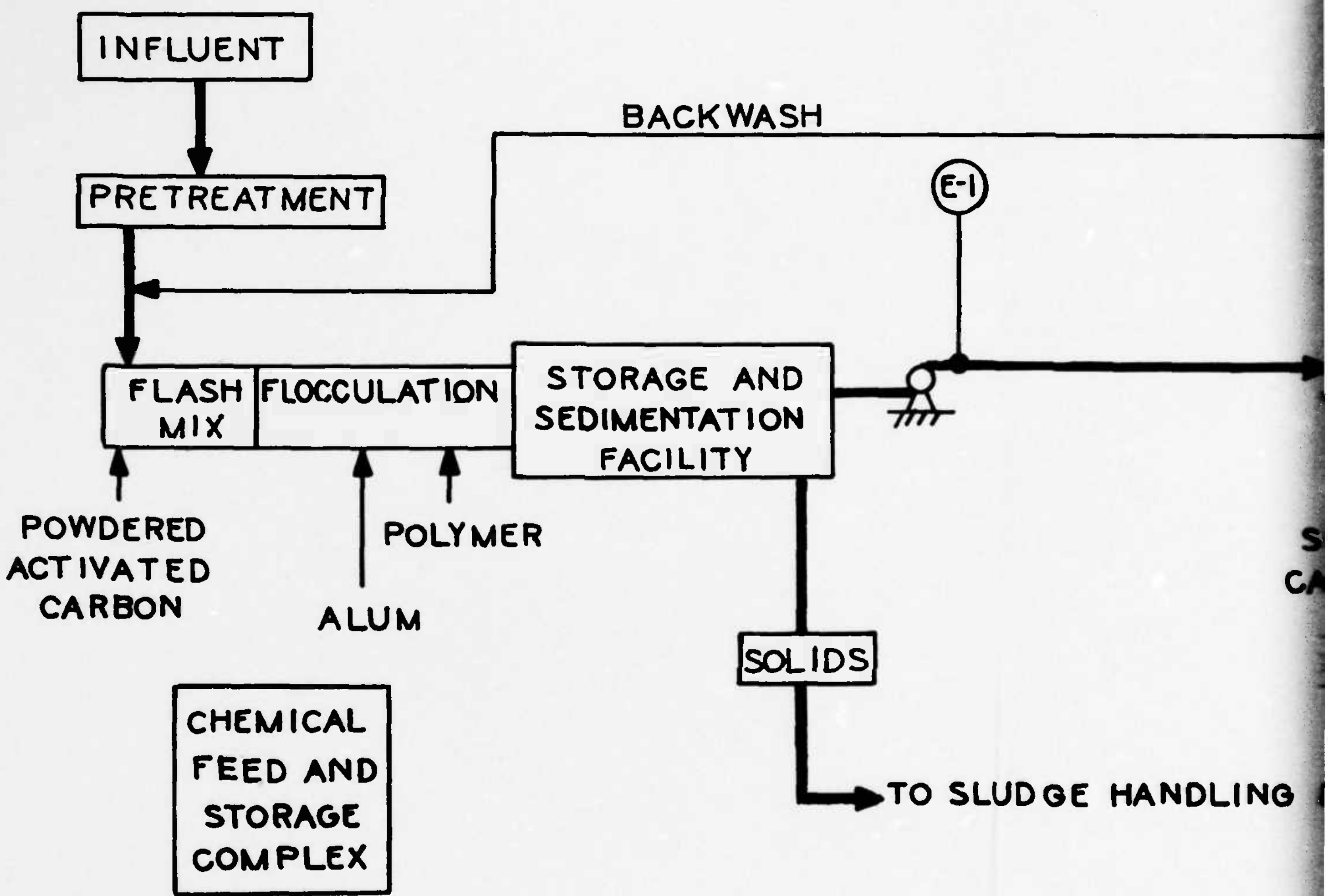


EDIMENTATION BASIN =2400 GAL. M.G. OF COMBINED SEWER OVERFLOWS
DIMENTATION BASIN = 600 GAL. M.G. OF STORM WATER

2

FIGURE B2

TREATMENT SYSTEM FOR COMBINED OVERFLOWS TO MEET STATE GOALS



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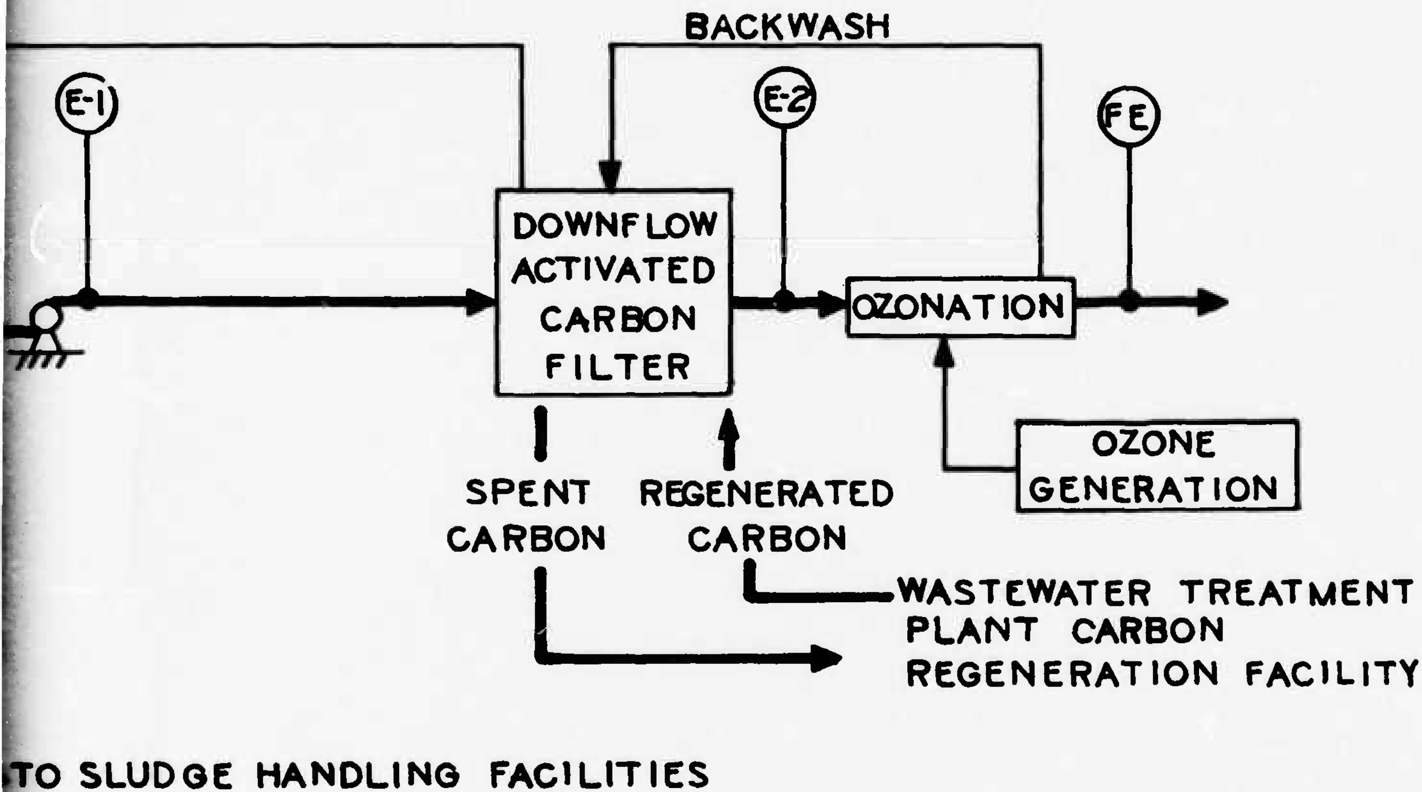
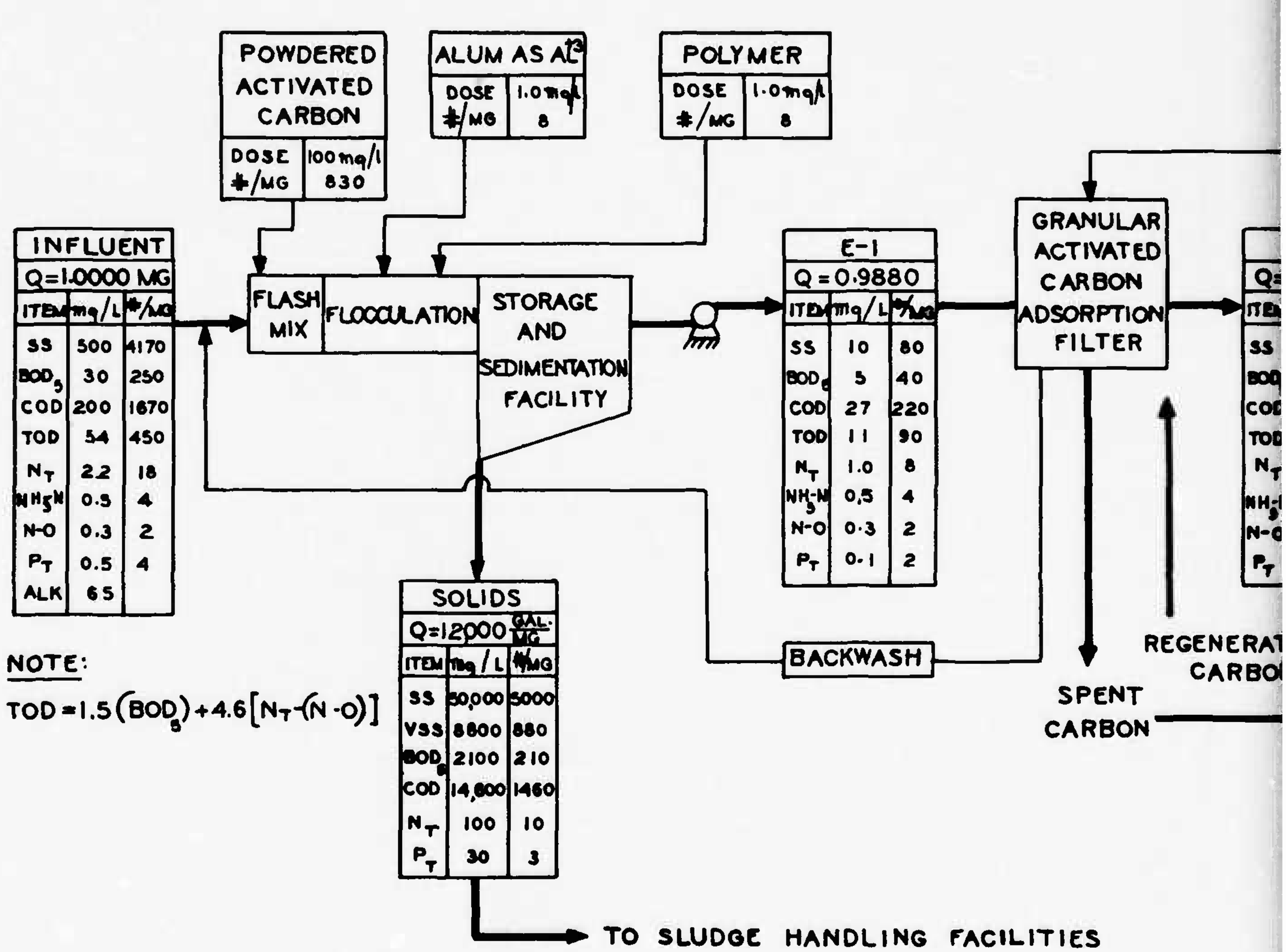
HAVENS AND EMERSON, LIMITED



2

FIGURE B 3

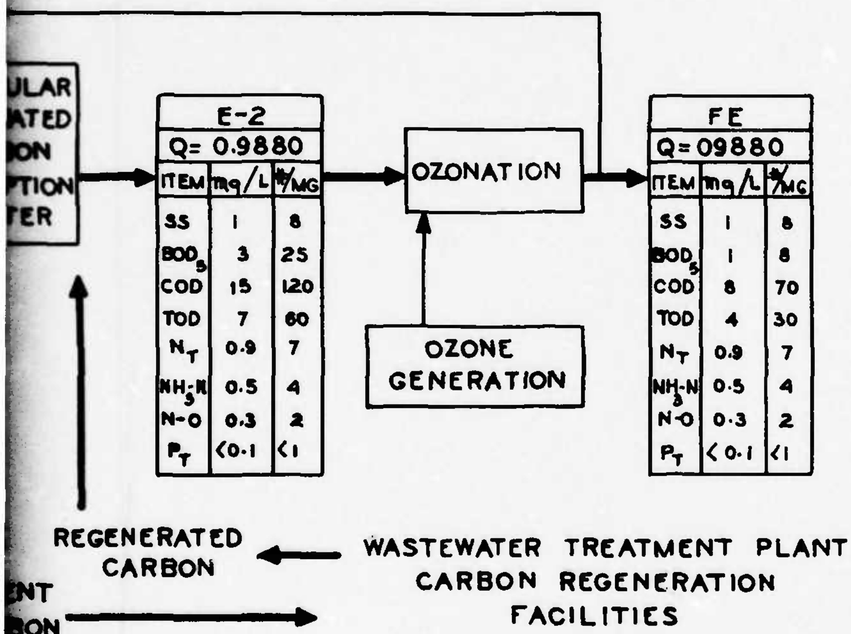
BASIC PHYSICAL-CHEMICAL TREATMENT SYSTEM FOR STORMWATER TO MEET FEDERAL GOALS



NOTE:

$TOD = 1.5(BOD_5) + 4.6[N_T - (N\text{-}O)]$

/

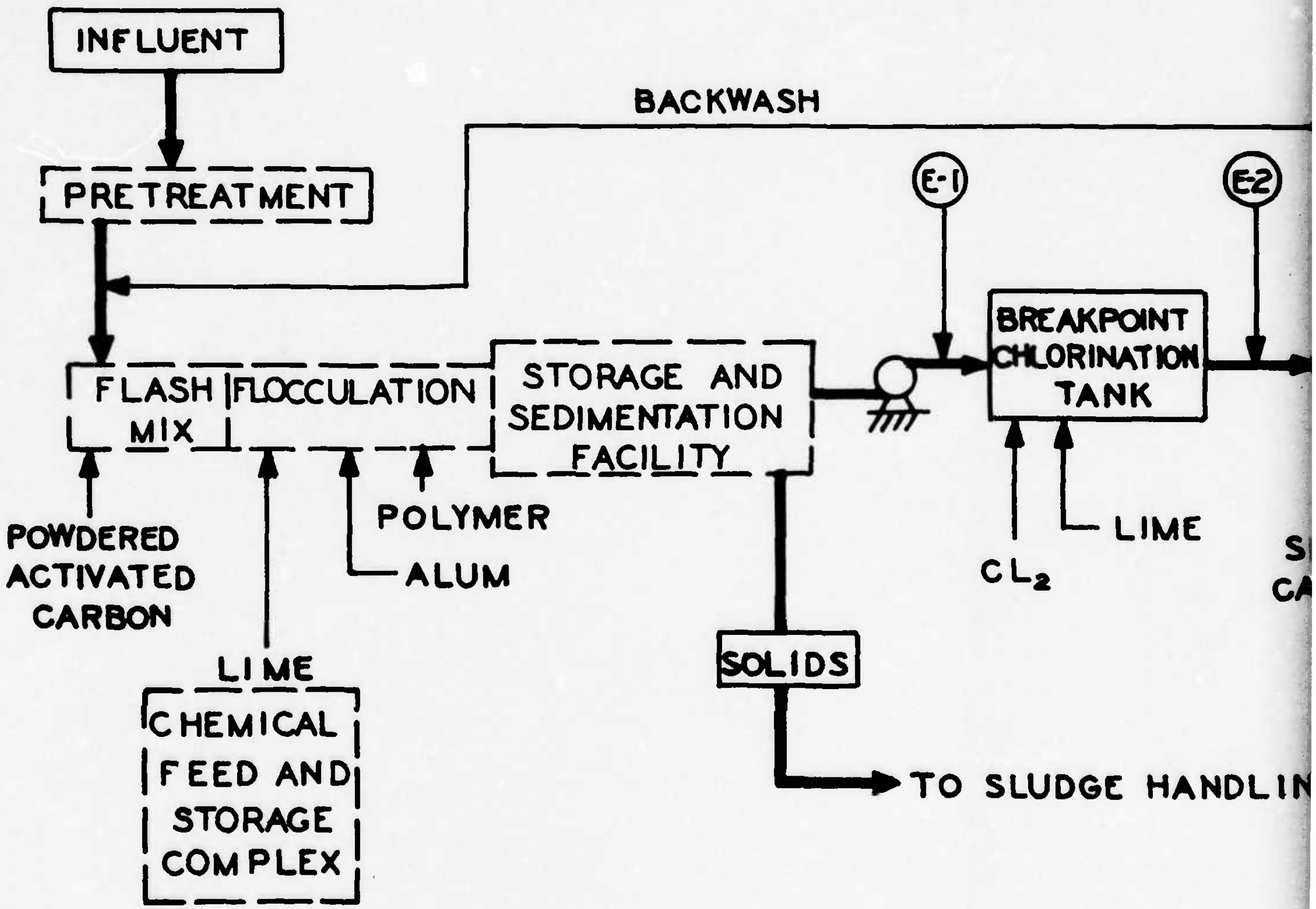


ITEM	REMOVABLE EFFICIENCIES-%		
	E-1	E-2	FE
SS	98	99+	99+
BOD_5	83	90	97
COD	86	93	96
TOD	80	87	93
N	56	61	61
P	75	>75	>75

2

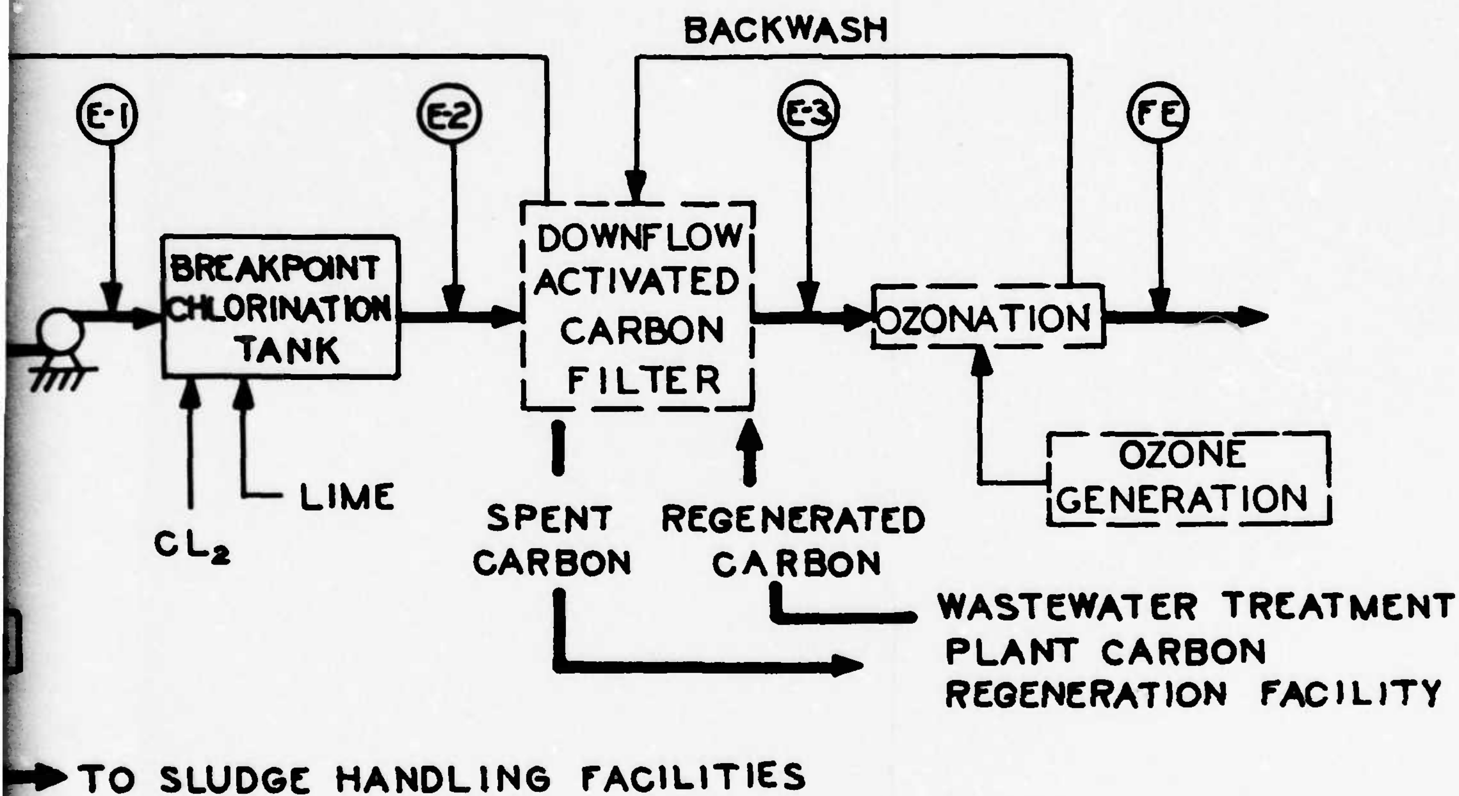
FIGURE B3A

TREATMENT SYSTEM FOR STORM WATER TO MEET FEDERAL GOALS



1

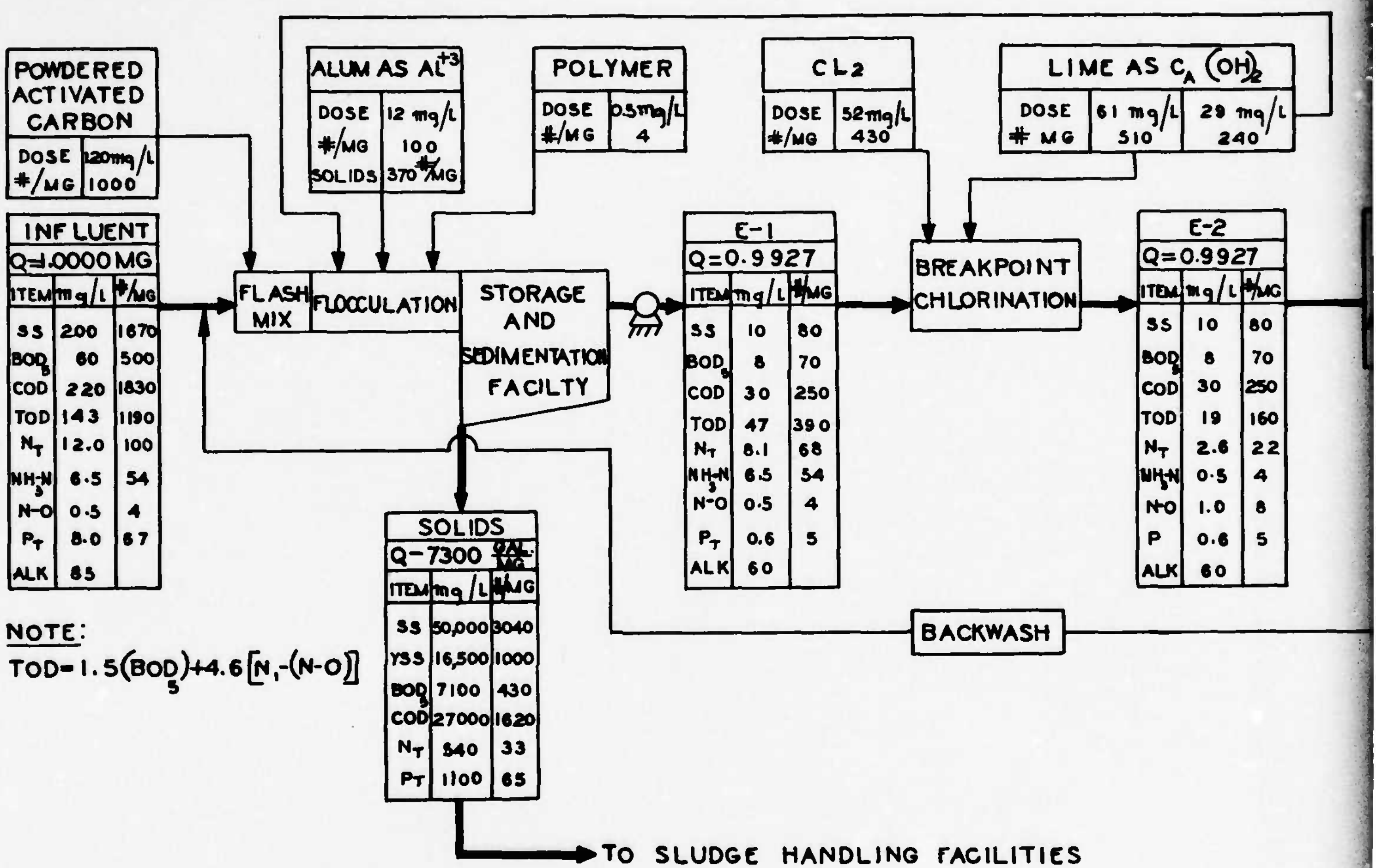
HAVENS AND EMERSON, LIMITED



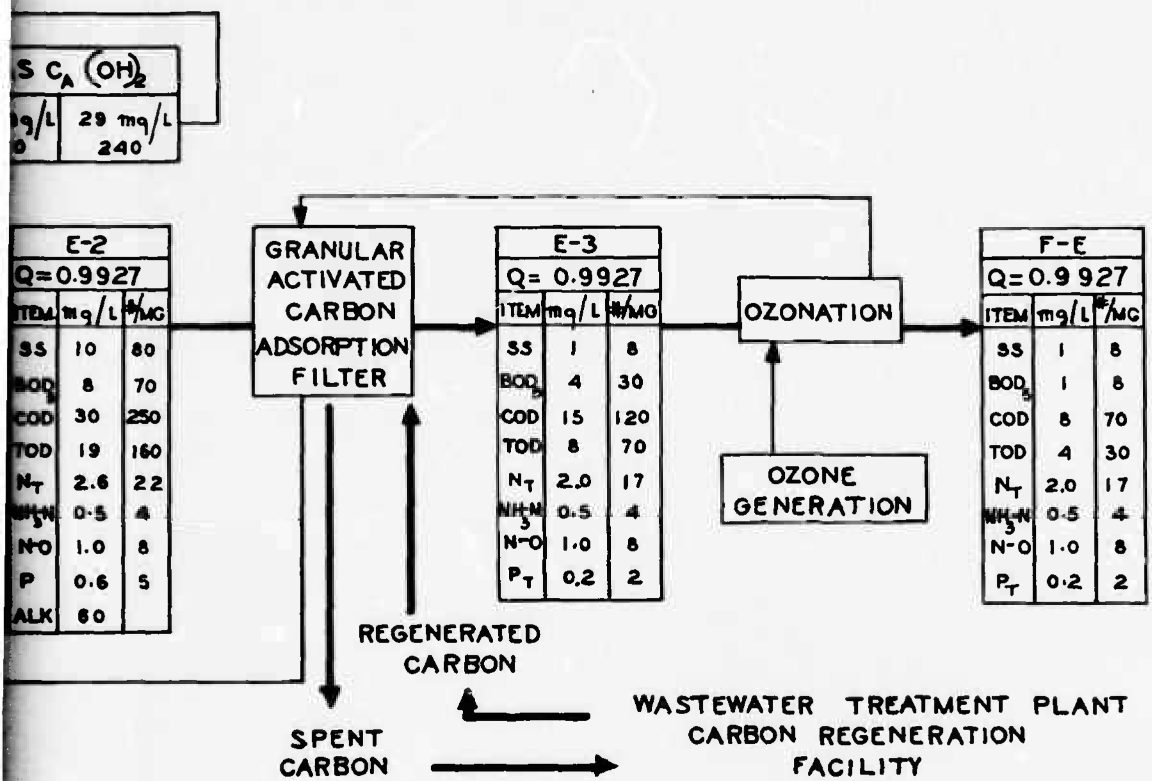
2

FIGURE B 4

BASIC PHYSICAL - CHEMICAL TREATMENT SYSTEM FOR COMBINED OVERFLOWS TO MEET FEDERAL GOALS



ITEM	REMOVAL EFFICIENCIES — %			
	E-1	E-2	E-3	FE
SS	95	95	99+	99+
BOD_5	87	87	93	98
COD	86	86	93	96
TOD	67	87	94	97
N_T	32	78	83	83
P_T	93	93	97	97



2

FIGURE B4A

TREATMENT SYSTEM OF COMBINED OVERFLOWS TO MEET FEDERAL GOALS

2. DESIGN CRITERIA

The design criteria for the stormwater system is similar to the wastewater system. The unit processes or items that are different are presented herein.

2.1 COLLECTION

The collection system is that network of pipes required to pick up the local storm drains and deliver the water to the treatment plant or storage site. In areas where development is not sufficient to warrant a storm drainage system but where growth indicates the need at a later decade, the collection system was laid out to intercept the natural drainage patterns. The collection system was designed to carry the one year peak flow either natural or adjusted. The 2020 land use was used for the design. As discussed in the Phase I report, land use changes were accounted for. Further adjustments were made in undeveloped areas to account for changing development patterns and are discussed in Section 3.2.

2.2 ADJUSTMENT FOR PLANNED UNIT DEVELOPMENT ZONING

Stormwater flows can be reduced in future developments by appropriate planning if the concept of Planned Unit Development (P.U.D.) is adopted. The storm runoff from the developed portion of the area would be treated, whereas the runoff from the green space or recreational area would not be treated. This, of course, is different from the usual urban sprawl development in that the storm water from the occupied area would be physically separated. It was assumed that the P.U.D. concept would not be widespread until 1980. Only areas that have an imperviousness factor of 10% or less in 1980 would be available for P.U.D. construction. To account for a more dense development around cities, the projected imperviousness factor also had to be less than 40% in 2020.

Figure B5 illustrates the rationale used in the development of the modified runoff volumes. As the fraction impervious increases, the volume of runoff increases, from a theoretical Q_o, at zero fraction impervious. Q_o can be calculated as follows:

$$Q_o = Q_b - I_b \left(\frac{Q_b - Q_a}{I_b - I_a}\right)$$

Q_o = Total annual runoff volume at zero fraction impervious

Q_a = Total annual runoff volume for 1970 (m.g.)

Q_b = Total annual runoff volume for 2020 (m.g.)

I_a = Percent impervious for 1970 expressed as a decimal

I_b = Percent impervious for 2020 expressed as a decimal

Assuming that the total runoff will be treated when an area reaches 0.40 fraction impervious it can be seen that the runoff from the undeveloped portion will decrease from Q_o to zero at 0.40 fraction impervious. Knowing this, the total runoff which must be treated, Q_m, can be calculated:

$$Q_m = I_b\left[2.5Q_b + \left(\frac{Q_b - Q_a}{I_b - I_a}\right)(1-2.5I_b)\right],$$

Q_m = Modified annual runoff volume to be collected and treated in 2020 (m.g.).

2.3 STORAGE SEDIMENTATION BASIN WITH SEPARATE TREATMENT FACILITIES

Under the plans with separate treatment facilities, the storage sedimentation basins are of either concrete or earth construction. Concrete basins are assumed in urban areas where land is at a premium and a public nuisance or hazard exist. The earth storage basins are assumed in suburban areas where the basins with adequate buffer zones can be incorporated in the planning of the area, and cost could be minimized. The balance between storage and treatment has been optimized and is shown in Figure B6. The optimum rates of treatment to storage varies from 25 to 40% of the peak flow. The treatment units are designed to be capable of treating 30%

of the peak flow, and the storage basin has capacity to store the remainder of the hydrograph plus two hours detention volume based on the treatment rate of 30% of the peak flow.

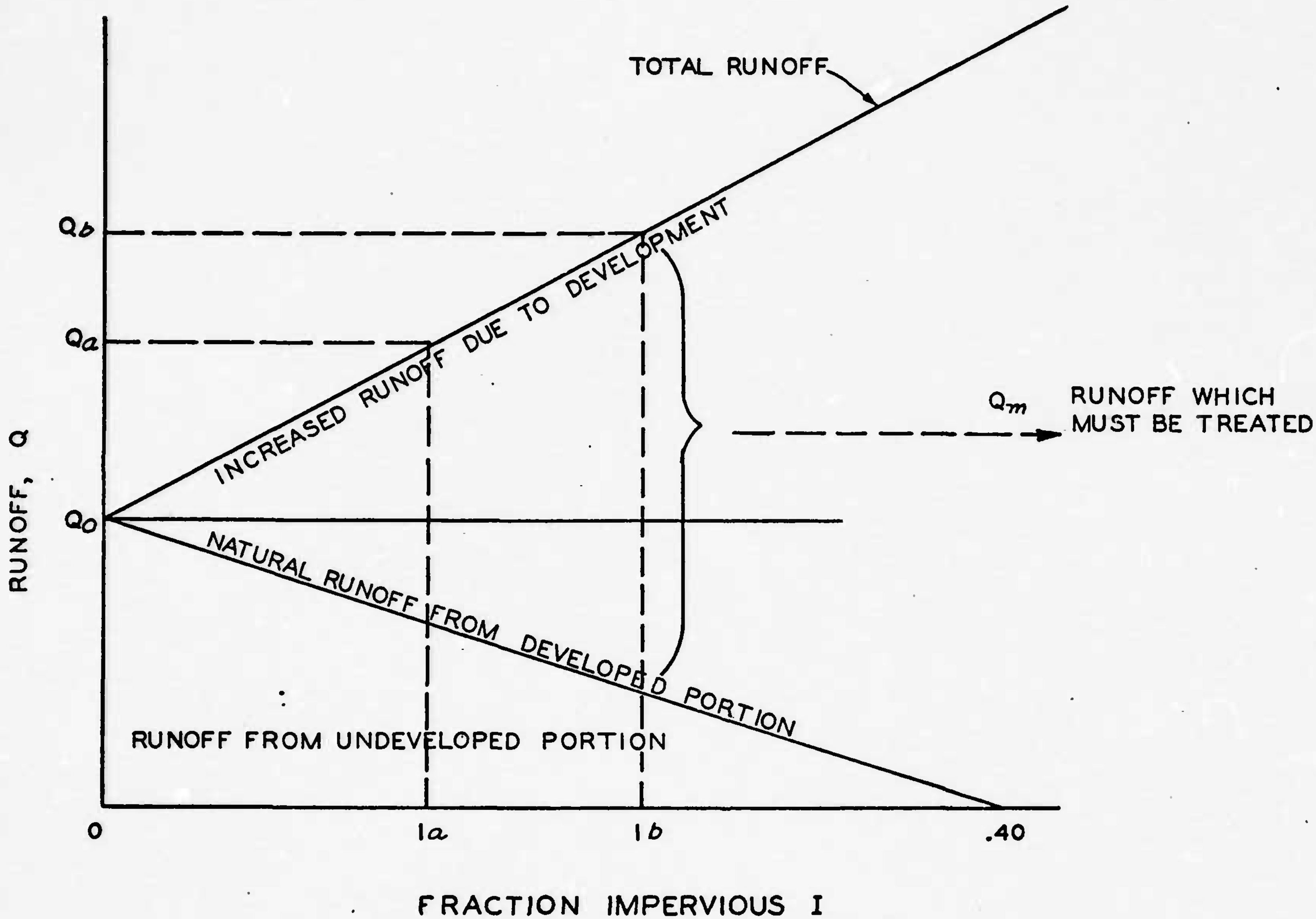
The earth basins would be designed into the developments and utilized as green space or parks. The storage capacity of the basins is equivalent of the one year design storms. The treatment units would have capacity to empty the basin in three days.

The concrete basins would also be used for combined sewage overflows. Sludge in the combined sewer concrete basins is collected and pumped or trucked to a municipal plant for final disposal.

Sludge is collected in the separate concrete and earth basins and taken to a central sludge disposal area.

2.4 STORAGE BASINS WHEN RELEASED TO MUNICIPAL TREATMENT PLANTS

Under the plans where the storm water or combined sewer overflow is stored and released to plants, the volume of storage is equal to 20% of the annual runoff for the earth basins and the 1-year storm volume for concrete basins. In stormwater basins, the pump out capacity is designed to empty the basin in thirty (30) days and in the combined sewer overflow areas the pump out capacity is three (3) days. Both concrete and earth basins are used, with only concrete being used for the combined sewer area. Sludge is not removed in the concrete basins but is collected and pumped with the outfall to the municipal plant. In the earth basins, the sludge would be removed by earth moving machinery on an annual basis.



$$Q_m = I_b\left[2.5Q_b + \frac{Q_b - Q_a}{I_b - I_a}(1 - 2.5\,I_b)\right]$$

FIGURE B5
STORMWATER FLOW
REDUCTION FORMULA

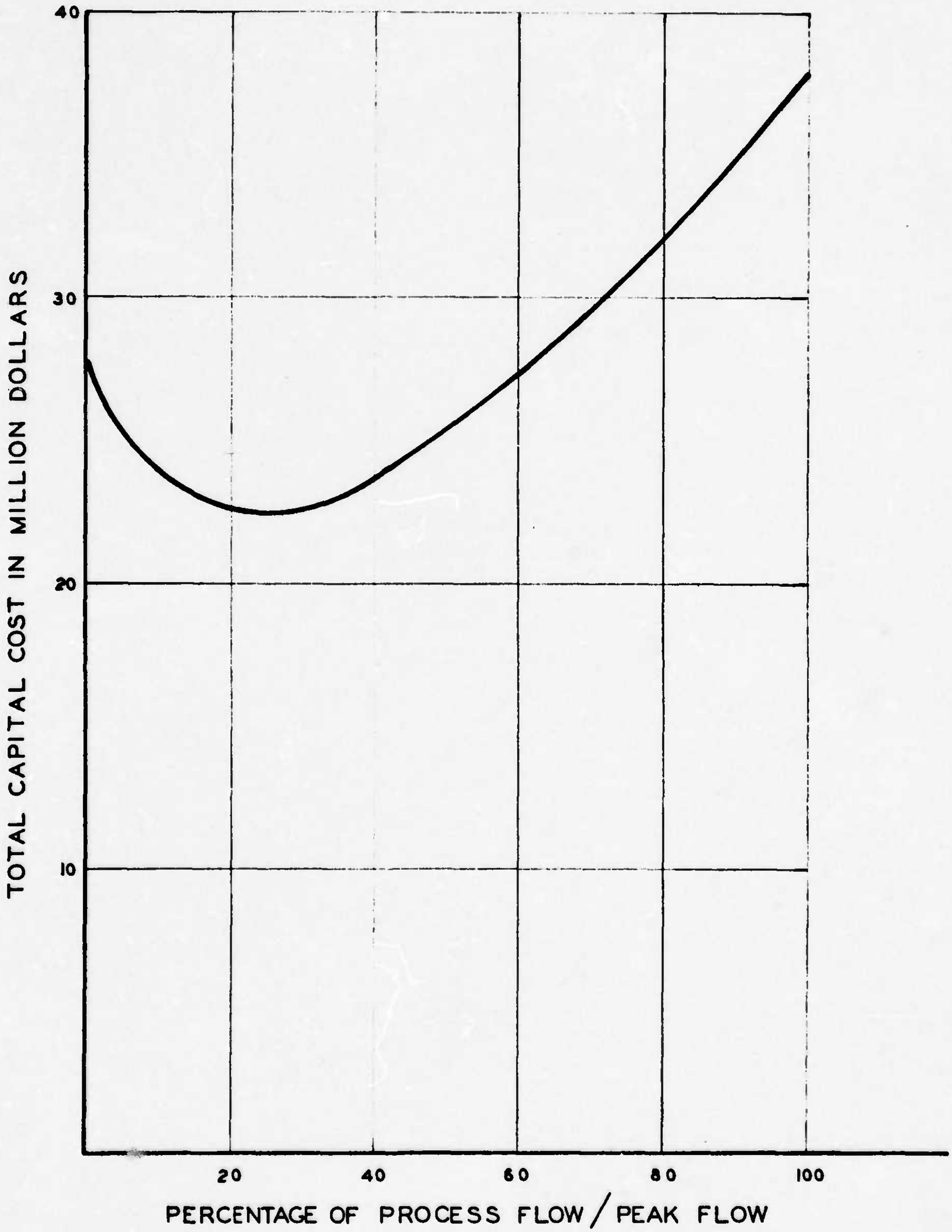


FIGURE B6
COST OPTIMIZATION
STORMWATER TREATMENT
TO LEVEL:I W/CONCRETE BASIN

3. UNIT COSTS

Table B2 shows a list of various unit capital costs of processes used for treatment of separate stormwater and combined sewer overflows to Level 1 and Level 2. These costs were used in preparation of cost estimates for the alternative plans, and were based on January, 1972 cost with ENR construction index of 1740.

3.1 CAPITAL COST

The reference numbers follow the process being discussed.

TABLE B2

SEPARATE STORMWATER AND COMBINED SEWER OVERFLOWS
UNIT CAPITAL COST
FIGURE IDENTIFICATION

Separate Stormwater w/earth Basin - Level 1	B7
Separate Stormwater and Combined Sewer Overflows w/concrete Basin - Level 1	B8
Separate Stormwater w/earth Basin - Level 2	B9
Separate Stormwater w/concrete Basin - Level 2	B10
Combined Sewer Overflows w/concrete Basin - Level 2	B11
Earth Basin	B12
Microstrainers	B13

These processes are briefly discussed below to identify design parameters, the items included in each process, and the cost data reference.

Separate storm with Earth Basin - Level 1, Figure B7 represents the total construction cost of treatment as shown on the schematic diagram of Figure 41, and includes diversion and screening, earth storage and sedimentation basin, pumping, microstrainers, backwash sedimentation and ozonation. Ref. 21,1,4,16,9

Separate storm and combined sewer overflows - Level 1, Figure B8

represents the total construction cost of treatment as shown on the schematic diagram of Figure B2, and includes diversion and screening, concrete storage and sedimentation basin, pumping, microstrainers, backwash sedimentation and ozonation. Ref. 22,1,4,16,9

Separate stormwater w/earth Basin - Level 2, Figure B9 represents the total construction cost of treatment as shown on the schematic diagram of Figure B3, and includes diversion and screening, earth storage and sedimentation with chemicals, pumping, carbon filter and ozonation. Ref. 21,1,14,12,9,11

Separate stormwater w/concrete Basin - Level 2, Figure B10 represents the total construction cost of treatment as shown on Figure B4, and includes diversion and screening, concrete storage and sedimentation with chemicals, pumping, carbon filter and ozonation. Ref. 22,1,14,12,9,11

Combined sewer overflows w/concrete Basin - Level 2, Figure B11 represents the total construction cost of treatment as shown on Figure B4, and includes diversion and screening, concrete storage and sedimentation with chemicals, pumping, breakpoint chlorination, carbon filter and ozonation. Ref. 22,1,14,12,9,11

Earth Basin Figure B12 represents the total construction cost of earth storage basin with depth of 10-15 ft. Ref. 21

Microstrainers Figure B13 represents the total construction cost for microstrainers with a hydraulic loading of 1200-1600 gal./sq.ft./hr. using a Mark 0 (23 micron) screen.

3.2 OPERATION AND MAINTENANCE UNIT COSTS

Facilities for stormwater and combined sewer overflows treatment will be intermittently operated to treat flows from rainfall events as they occur. Therefore, cost data, which is available from various references and based on continuous operation, was multiplied by a reduction factor to reflect the intermittent nature of treatment.

Most of the operation and maintenance unit cost data available was based on rate of flow, but since rate of flow is variable during each storm and from one storm to another, it will be logical to base O & M cost on volume of stormwater and combined sewer overflows. To accomplish this, a detailed design was worked out for a typical storm subdistrict and all units of treatment were sized for Level 1 and Level 2 according to the basis of design discussed before. The cost of chemicals required for each process was also included. Ref. 5,1,4,16,12,22

Following is a summary of this cost analysis:

TABLE B3

OPERATION AND MAINTENANCE UNIT COST

Process	Unit O & M Cost Dollars/Million Gallon
1 - Concrete Storage (Based on 20% of Annual Volume)	68
2 - Earth Storage (Based on 20% of Annual Volume)	33
3 - Level 1: Treatment w/Concrete Basin	62
4 - Level 1: Treatment w/Earth Basin	35
5 - Level 2: Separate Stormwater Treatment w/Earth Basin	250
6 - Level 2: Separate Stormwater Treatment w/Concrete Basin	290
7 - Level 2: Combined Sewer Overflow Treatment w/Concrete Basin	385

The above mentioned operation and maintenance unit costs are further described below:

Concrete Storage: This storage was sized to receive 20% of the total annual runoff and would be used to store stormwater or combined sewer overflows before release for treatment at domestic waste treatment plant. Concrete storage basin will be provided with mechanical sludge

collectors. The operation and maintenance cost includes manpower, materials supply and electric power required for screening, basin with collectors and pumping.

Earth Storage: Capacity was based on 20% of the total annual runoff and would be used to store stormwater before release for treatment at domestic wastewater treatment plant. The operation and maintenance cost includes manpower, materials supply and electric power required for screening, basin and pumping.

Level 1 - Treatment w/Concrete Basins: The capacity of storage-sedimentation basin in this process is designed according to the basis of design in article II-B-3, and this volume is considerably less than the concrete storage mentioned above in Concrete Storage. The operation and maintenance cost includes manpower, materials supply and electric power required for screening, storage and sedimentation with collectors, pumping, microstrainers and disinfection.

Level 1 - Treatment w/Earth Basin: The capacity of storage-sedimentation basin in this process is designed to receive the volume of one-year storm which is less than 20% of annual volume used for earth storage mentioned above in Earth Storage. The operation and maintenance cost includes manpower, materials supply, and electric power required for screening, storage-sedimentation pumping, microstrainers and disinfection.

Level 2 - Separate Stormwater Treatment w/Earth Basin: Storage-sedimentation basin capacity is the same as in Level 1 mentioned above. Chemical cost is substantial and includes: powdered activated carbon: 89 $/MG, ozone: 50 $/MG, granular activated carbon (make up) 8 $/MG a total chemical cost of 188 $/MG. In addition to chemical cost, the

operation and maintenance cost includes manpower, materials supply and electric power required for screening, flash mixing and flocculation, storage and sedimentation, pumping, activated carbon filter and ozonation.

Level 2 - Separate Stormwater Treatment w/Concrete Basin: This process is similar to the one described in Level 2 above except for concrete storage sedimentation basin with sludge collectors.

Level 2 - Combined Sewer Overflows Treatment w/Concrete Basin: The capacity of storage-sedimentation basin in this process is the same as described in Level 1 - Treatment w/Concrete Basins above, and is provided with mechanical sludge collectors. The chemical cost constitutes a major portion of the operation and maintenance cost. The chemical cost includes: powdered activated carbon: 100 $/MG, Lime: 3 $/MG, Alum: 26 $/MG, polymer: 5 $/MG, chlorine for solids stabilization: 35 $/MG, chlorine for breakpoint chlorination: 22 $/MG, lime for breakpoint chlorination: 5 $/MG, ozone: 50 $/MG, granular activated carbon (filter make up) 8 $/MG, a total chemical cost of 254 $/MG.

In addition to chemical cost, the operation and maintenance cost includes manpower, materials supply, and electric power required for screening, flash mixing and flocculation, storage and sedimentation, pumping, breakpoint chlorination, activated carbon filter and ozonation.

Breakpoint chlorination O & M cost was based on a chlorine dosage of 8 x ammonia nitrogen concentrators in the influent.

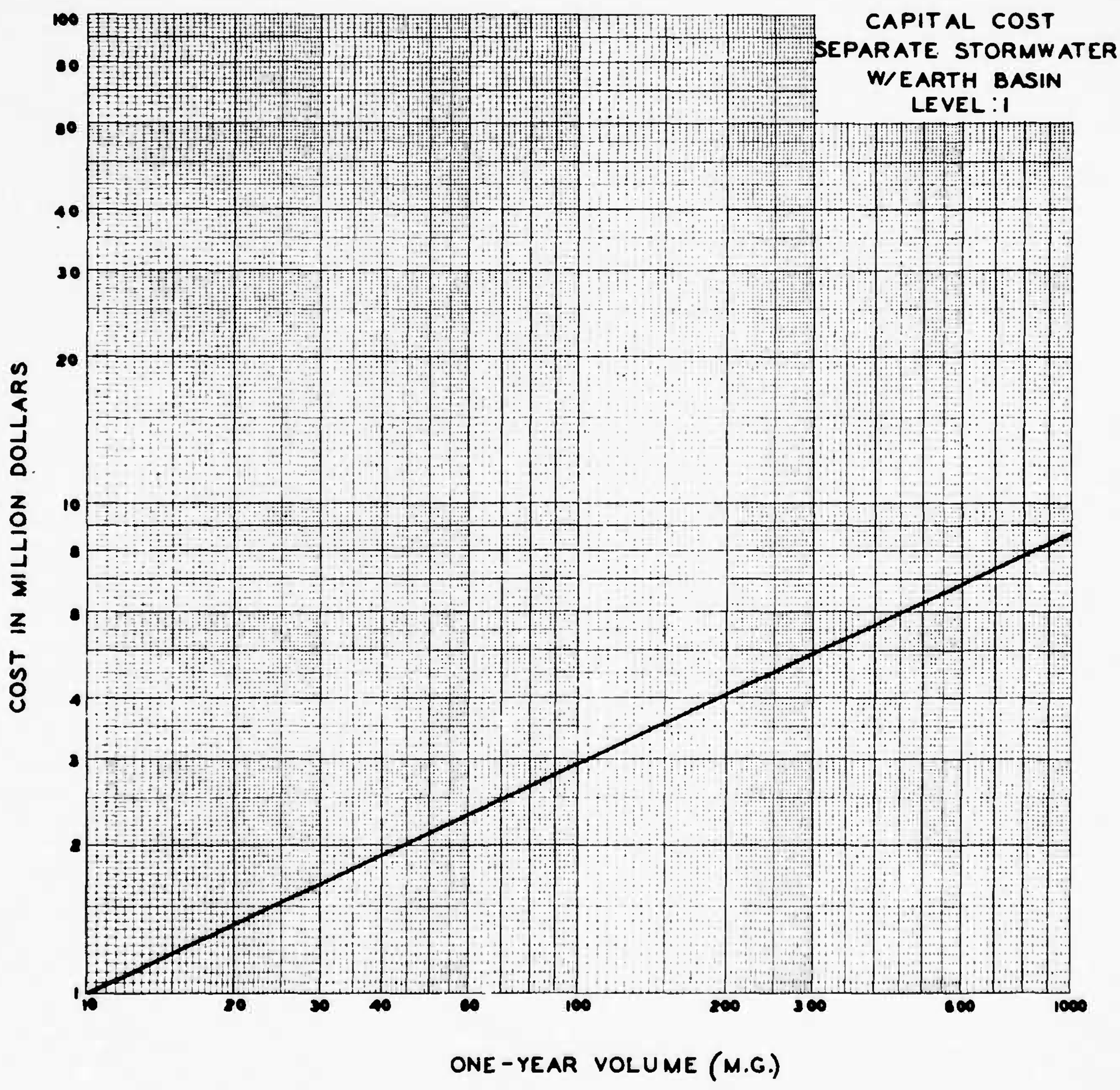

CAPITAL COST
SEPARATE STORMWATER
W/EARTH BASIN
LEVEL:1
COST IN MILLION DOLLARS
ONE-YEAR VOLUME (M.G.)
100
80
60
40
30
20
10
8
6
4
3
2
1
10
20
30
40
60
100
200
300
600
1000

Figure No. B7

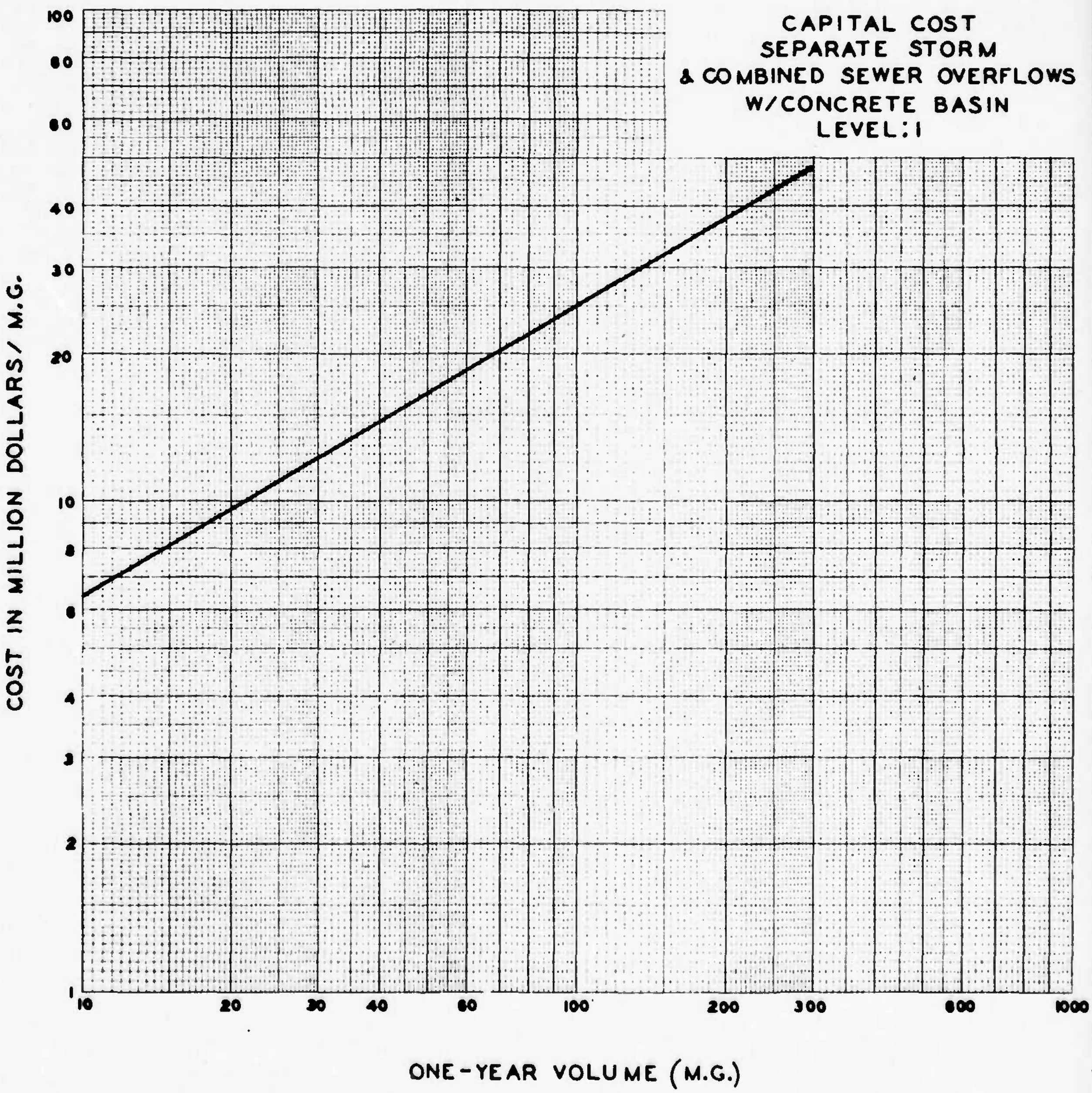

CAPITAL COST
SEPARATE STORM
& COMBINED SEWER OVERFLOWS
W/CONCRETE BASIN
LEVEL: I
COST IN MILLION DOLLARS/ M.G.
ONE-YEAR VOLUME (M.G.)
100
80
60
40
30
20
10
8
6
4
3
2
1
10
20
30
40
60
100
200
300
600
1000

Figure No. B8

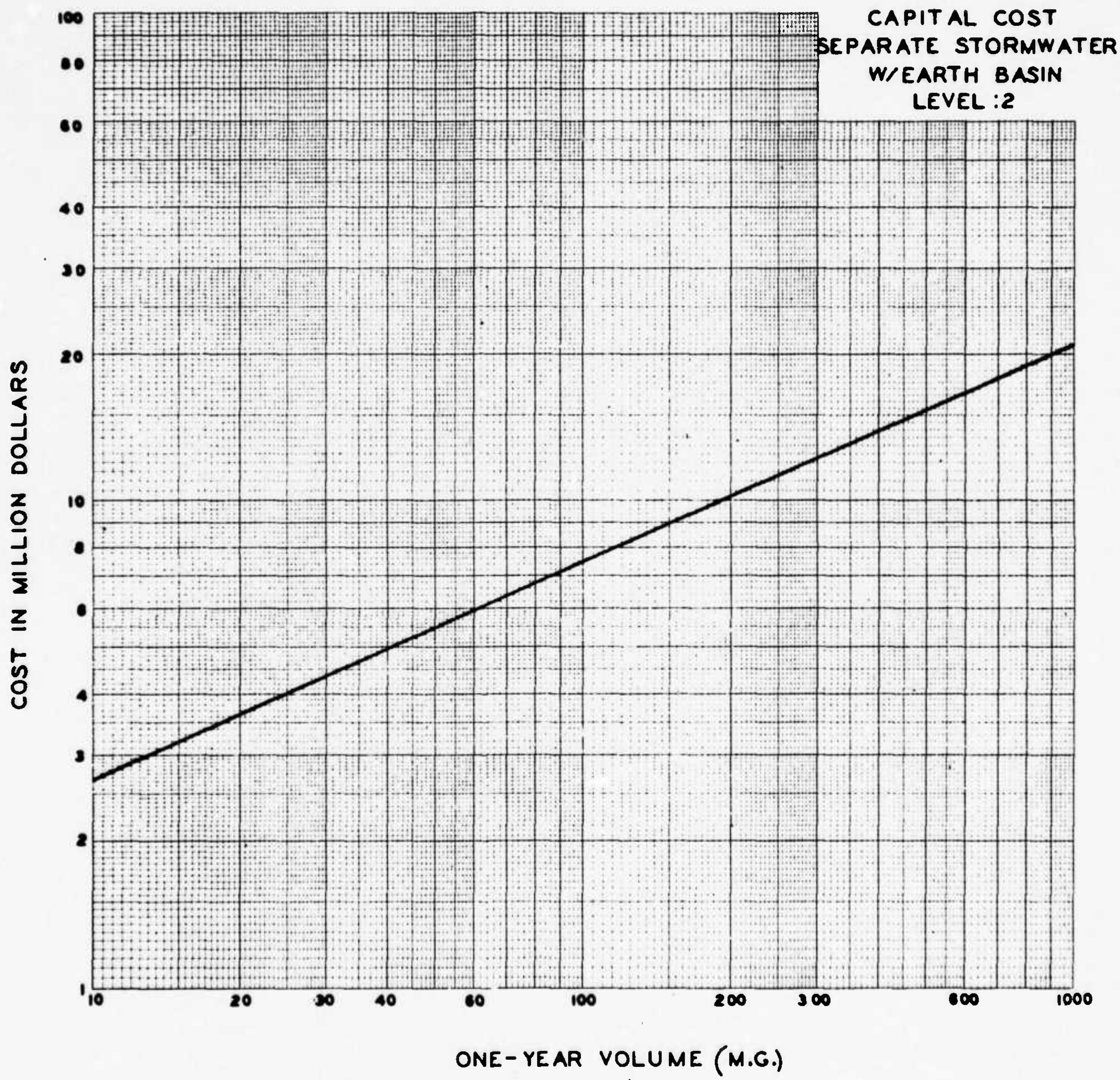

CAPITAL COST
SEPARATE STORMWATER
W/EARTH BASIN
LEVEL :2
COST IN MILLION DOLLARS
ONE-YEAR VOLUME (M.G.)
100
80
60
40
30
20
10
8
6
4
3
2
1
10
20
30
40
60
100
200
300
600
1000

Figure No. B9

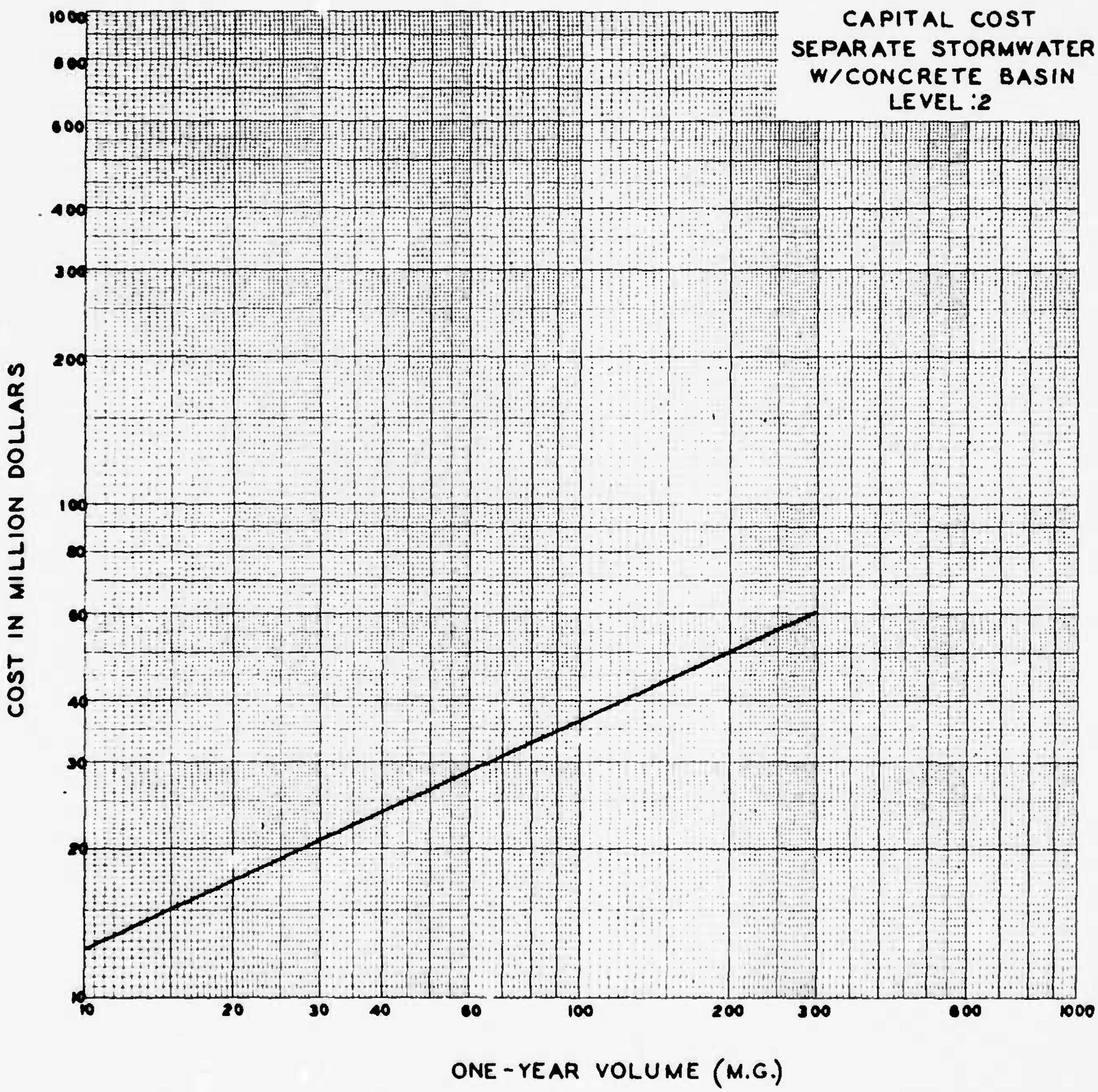


Figure No. B10

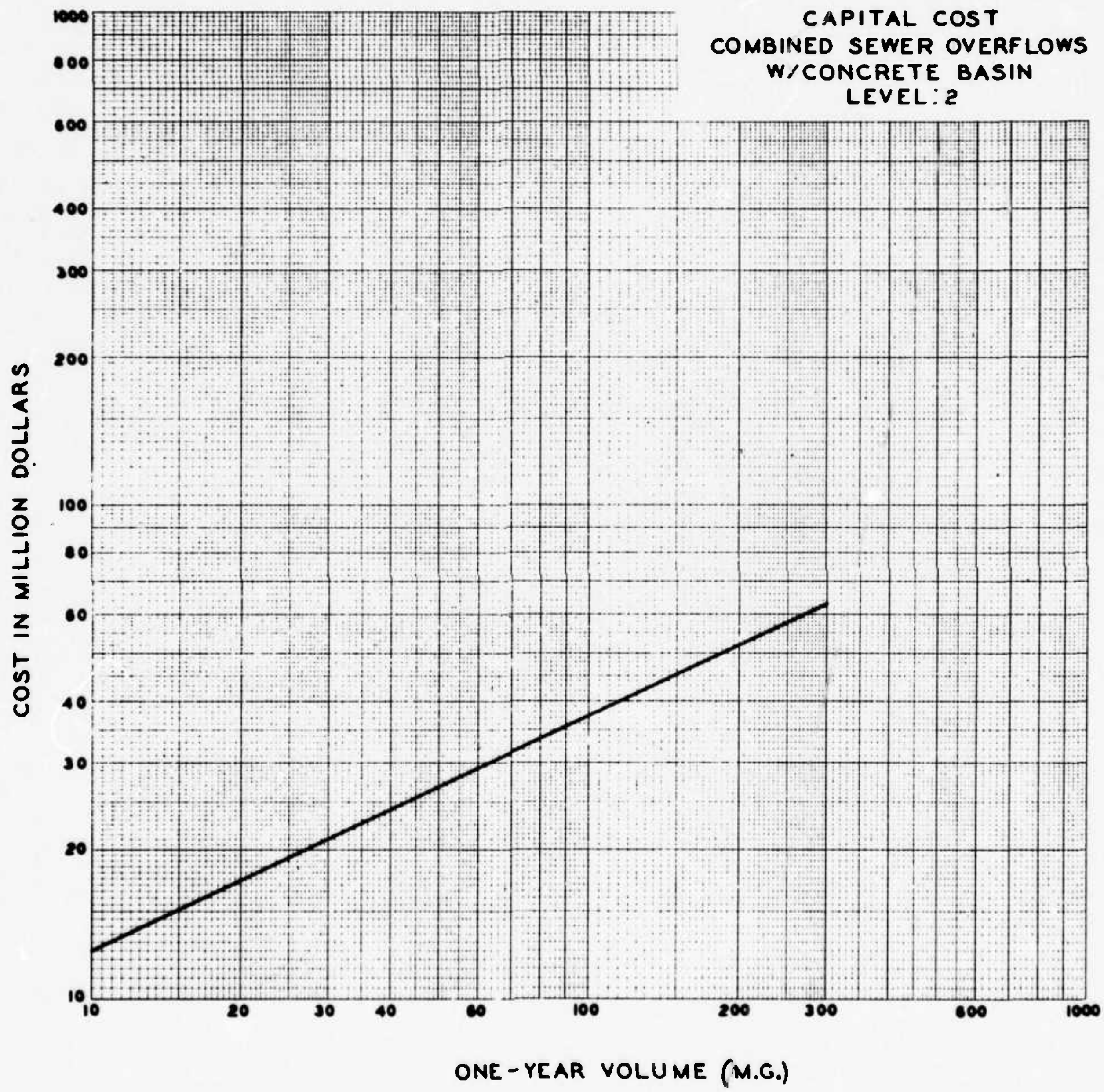


Figure No. B11

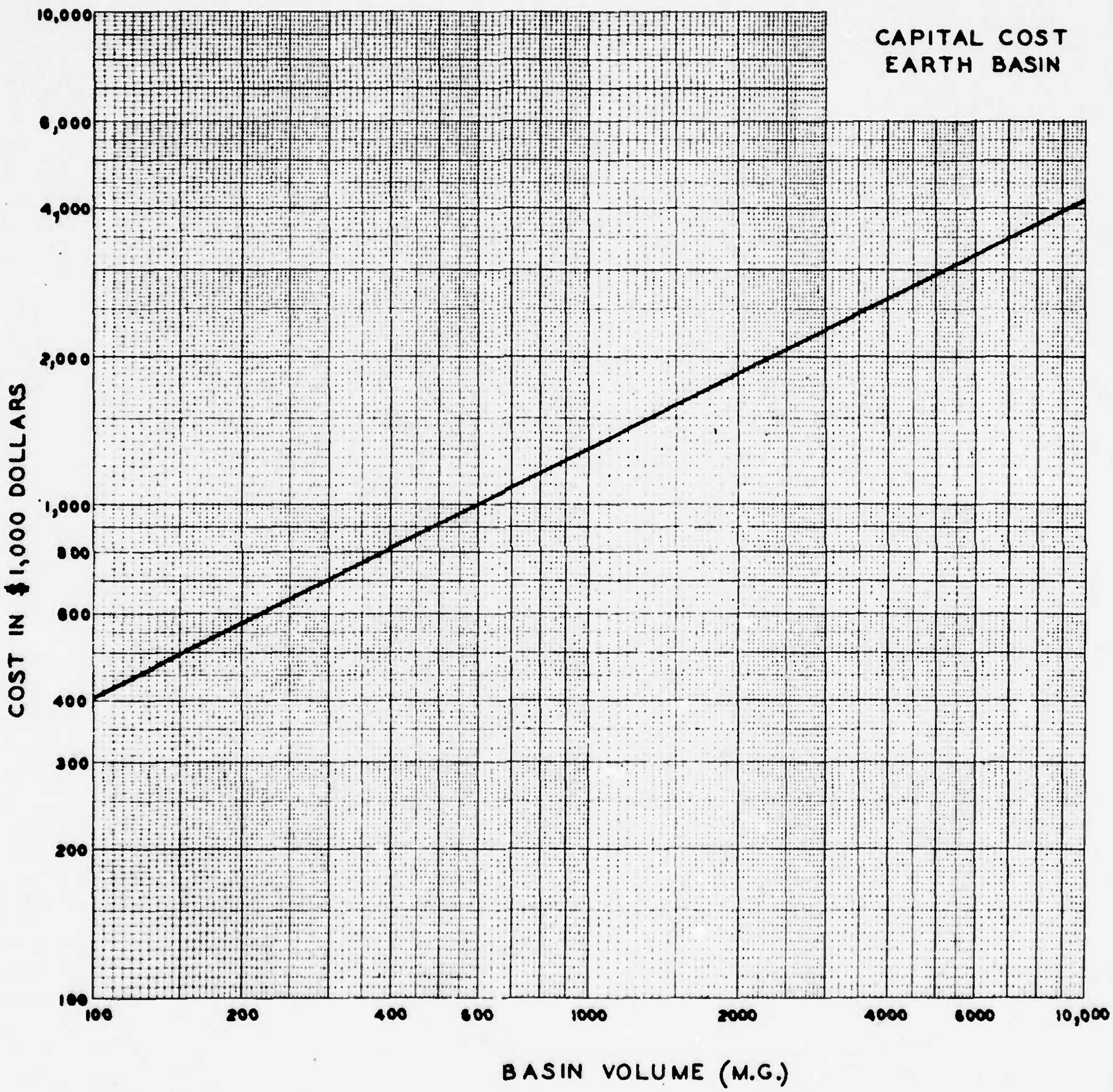


Figure No. B12

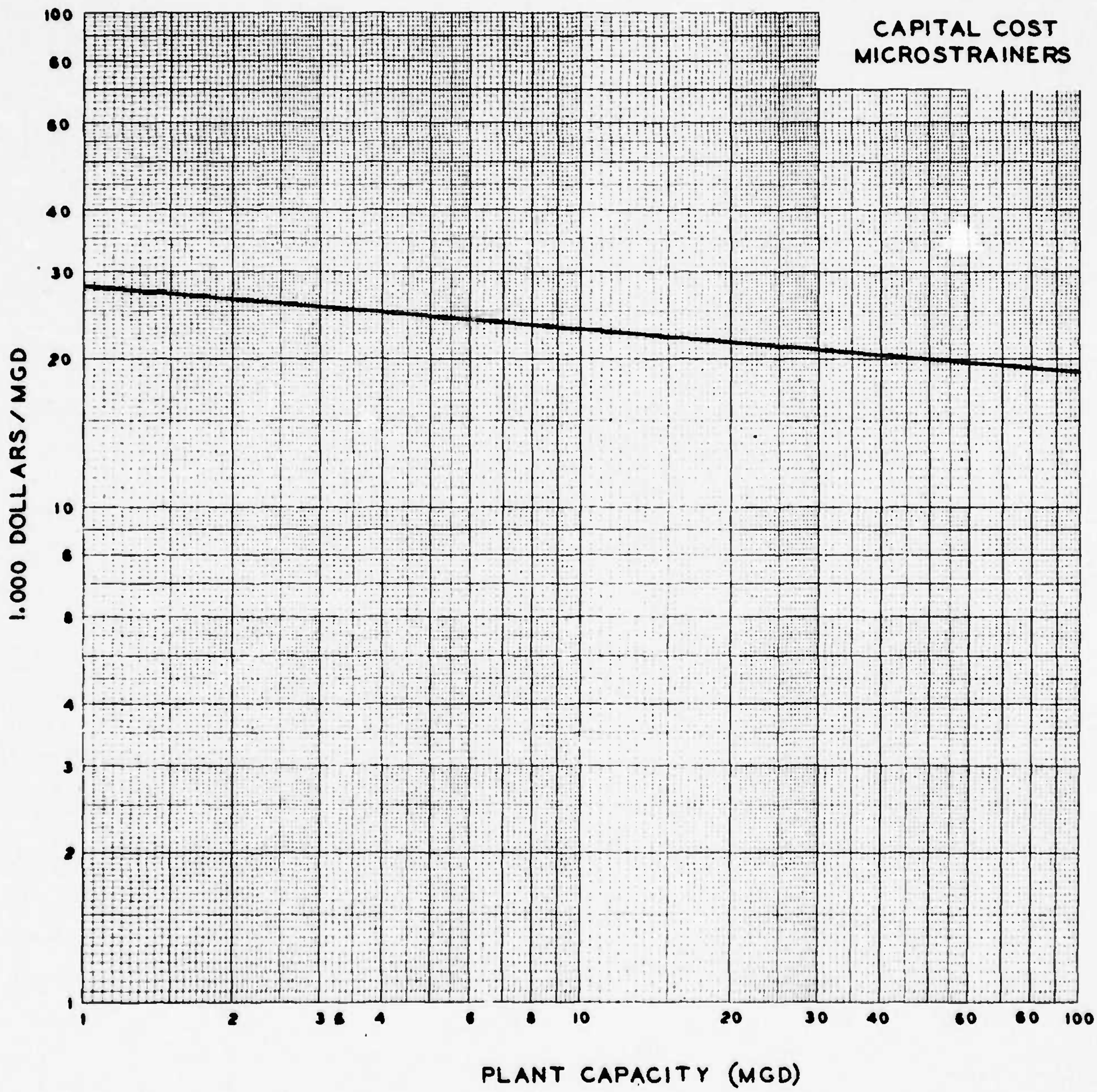


Figure No. B13

4. STORM WATER PLAN FORMULATION ALTERNATIVES

This section presents a discussion of the alternatives considered for storm water treatment in formulation of the wastewater management plans.

4.1 Design Storm Alternative

A study of the hydrology of the study area, and of the runoff generated by storms of various intensities and frequencies was made in the Phase I portion of the Survey Scope Studies. As a result of these investigations, the 1-year storm was recommended as the design storm for the runoff collection and treatment system. For details of this subject, the reader is referred to the Phase I report, but a discussion of this matter is presented here for amplification and for comparison with the plans prepared in the Chicago area studies.

As established in the Phase I hydrologic studies, the 1-year design storm yields runoff at a peak rate of approximately 0.5 cfs per acre, which is the critical design value used to size elements of the collection system. This is the same runoff rate used in design of the collection system in the Chicago area studies. For storms of greater intensity, storm water runoff would be stored on the surface, in street gutters and in natural depressions and would eventually be conveyed to the storage and treatment facilities.

In the present Cleveland-Akron studies, two general plans of storm water treatment are used, depending on relative economy and local conditions. Where storm water is to be stored and treated in the municipal wastewater treatment plants, storage facilities

were designed to contain 20% of the total annual volume of runoff. This storage volume is equivalent to the volume necessary to contain runoff from the 100-year storm, and amounts to 1.26 inches of runoff over the gross area.

Where storm water is stored and treated at separate storm water treatment plants, the storage facilities were designed to contain the 1-year storm, equivalent to approximately 0.4 inches of runoff. Flows in excess of this volume would undergo screening, sedimentation and disinfection, so that no storm water flows would be discharged without some treatment. All flows up to the design 1-year storm would receive complete Level 1 and Level 2 treatment as called for by the particular alternative plan. In comparing these criteria to the preliminary design of the Chicago area system, several important differences in characteristics of the study area should be noted. Due to the intense urbanization in Chicago, a higher runoff factor was used, which results in a greater quantity of runoff from a given storm. As shown in Table B4a, the runoff from a 1-year storm in Chicago is approximately 1.0 inch whereas, in the Cleveland study area, the total runoff from a storm of the same frequency is 0.4 inches. For the 100-year storm, runoff in the Chicago area, is 2.5 inches compared with 1.26 inches in Cleveland.

Since the runoff intensity rate of 0.5 cfs per acre was used in both cases, and in both cases facilities for storage and treatment with municipal wastewater can accept runoff from the 100-year storm, the two systems are exactly comparable in this regard. It is

only in those instances in the Cleveland plan where storm water storage and treatment is handled separately from municipal treatment plants that the Cleveland design is based on retention and treatment of 0.4 inches, equivalent to the 1-year storm criteria. These figures are shown on Table B4a.

TABLE B4a

STORMWATER COLLECTION AND TREATMENT IN CLEVELAND-AKRON AREA COMPARED TO CHICAGO AREA

RAINFALL-RUNOFF	CHICAGO	CLEVELAND
1-year storm rainfall	1.80 inches	1.14 inches
1-year storm runoff	1.0 inches	0.4 inches
100 year storm rainfall	4.40 inches	3.60 inches
100 year storm runoff	2.5 inches	1.26 inches
Design discharge for pipes	0.5 cfs/acre	0.5 cfs/acre
Storage and Treatment with municipal wastewater	2.50 inches	1.26 inches
Storage and Treatment at separate stormwater plants	No comparable plan	0.40 inches

To further discuss this question, cost estimates were prepared for a collection system adequate to convey the 1, 10, and 100-year storm runoffs. Using the 1-year collection system cost as a base of 1, the cost ratio of the 10-year collection system would be 1.65, and of the 100-year systems would be 3.3. Expressed as a percentage of the total storm water collection and treatment cost, these values are respectively 32%, 43% and 60%.

The percentage of the total runoff treated under the different alternates for the 1-year and 100-year storms were computed and

compared to the Chicago plan. In addition, the estimated pollutant loads generated and the residual pollutant loads discharged to the receiving waters were calculated for comparison of the approximate overall benefit to be derived from the additional expenditures necessary.

Table B4b shows the total BOD and SS loads generated in the study area, together with the residual loads discharged to the receiving waters for a year including a 1-year storm occurrence compared with loads discharged for a year including a 100-year storm occurrence. The residual loads are calculated for the 100-year storm design and for the 1-year storm design, both to Level 2 treatment.

The table shows the reduction in residual loads in going from the 1-year to the 100-year design to be 0.83 percent of the total BOD load generated and 6.2 percent of the total SS load generated. These percentages are for a year including a 100-year storm occurrence.

For an average year, the percentage reductions would be even less. This appears to be a minimal improvement for an increased expenditure of 60%.

Finally, Table B4c shows a comparison between the Chicago and Cleveland-Akron designs in terms of residual loads discharged from the combined and urban stormwater discharges only. (Not including municipal sewage effluents). Although this comparison is only approximate because of differences in the study area, the table shows that the residual loads discharged in the two cases are closely comparable.

TABLE B4b

CLEVELAND AREA RESIDUAL ANNUAL STORMWATER RUNOFF LOADS INCLUDING A 1 AND 100 YEAR STORM OCCURRENCE

	Municipal Separate Sewage		Combined Overflow		Separate Stormwater		Total	
	1 Year	100 Year	1 Year	100 Year	1 Year	100 Year	1 Year	100 Year
2020 Flow mg/year (percent of total)	295,810 (78)	295,810 (75)	16,150 (4)	19,200 (5)	65,600 (18)	79,600 (20)	377,560 (100)	394,610 (100)
BOD Total 1000#/year (percent of total)	435,000 (96)	435,000 (95)	8,070 (2)	9,600 (2)	11,100 (2)	13,400 (3)	454,170 (100)	458,000 (100)
Suspended Solids, Total, 1000#/year (percent of total)	441,000 (68)	441,000 (63)	26,900 (4)	32,000 (5)	183,800 (28)	223,000 (32)	651,700 (100)	696,000 (100)
Residual BOD 1000 #/year with Level 2 treatment 100 year storm design (percent of total)	860 (82)	860 (79)	80 (8)	96 (9)	111 (10)	134 (12)	1,051 (100)	1,090 (100)
Residual SS (as above) (percent of total)	879 (45)	879 (41)	135 (7)	160 (7)	920 (48)	1,115 (52)	1,934	2,154
Residual BOD 1000#/year with Level 2 treatment 1 year storm design (percent of total)	860 (82)	860 (18)	80 (8)	1,610 (33)	111 (10)	2,411 (49) (49)	1,051 (100)	4,881 (100)
Residual SS (as above) (percent of total)	879 (45)	879 (2)	135 (7)	5,100 (11)	920 (48)	39,200 (87)	1,934 (100)	45,179 (100)

After consideration of these and other factors, the previously established storm design criteria is confirmed, and is used in the Phase II and III studies.

TABLE B4c

COMPARISON OF RESIDUAL ANNUAL STORMWATER RUNOFF LOADS INCLUDING A 1 AND 100 YEAR STORM OCCURRENCE

	CLEVELAND						CHICAGO Equivalent Area[1]	
	Combined Overflows		Separate Stormwater		Total		Total	
	1 Year	100 Years	1 Year	100 Years	1 Year	100 Years	1 Year	100 Years
Flow mg/year	16,150	19,200	65,600	79,600	81,750	98,800	98,000	152,000
BOD Total 1000 #/year	8,070	9,600	11,100	13,400	19,170	24,000	14,700	22,800
S.S. Total 1000 #/year	26,900	32,000	183,800	223,000	210,700	255,000	375,000	582,000
Residual BOD 1000 #/year Level 2 Treatment 100 year storm design	80	96	111	134	191	230	147	228
Residual SS (as above)	135	160	920	1,113	1,055	1,275	1,880	2,910

(1) For comparison, this data has been computed for an area of Chicago equal to the study area in the Cleveland-Akron Three Rivers Plan.

TABLE B5

COST OF INCREASED PROTECTION AND TREATMENT

100 Year Compared To 1 Year Runoff

		Ratio of Capital Cost Level 1	Ratio of Capital Cost Level 2
Alternative of Treatment with municipal wastewater*	Earth Basin	1.08	1.06
	Concrete Basin	1.67	1.66
Alternative of separate treatment	Earth Basin	2.56	2.52
	Concrete Basin	4.37	3.14

*low ratio results because with this scheme the storage capacity is 20% of the annual volume which is approximately equal to the 100 year storm. This capacity of storage is required in order to release low flows that can be conveyed in existing sewers and not overload the wastewater treatment plant.

4.2 STORAGE ALTERNATIVES

The construction of concrete storage basins is more expensive than constructing earth basins. Concrete basins have the advantages of being covered to prevent accidents, control odors, make sludge collection simpler and uses less land. The earth basins have the advantages of being less costly, providing additional green space, and could be developed into recreational areas.

For plans 1 and 2, the storm water runoff plans were formulated in two ways - one: all concrete basins; second, a combination of concrete basins and earth basins. With the combination plan, concrete basins were considered for all dense urban sites or areas that were already developed with storm and sanitary sewers when infiltration or illegal cross-connections were a problem. All combined sewer areas were supplied with concrete basins. The cost comparisons for these plans are shown in Table B6 and reflect cost for the unadjusted flows as described in 4.3. For a cost comparison, the plan was computed for a situation having all earth basins. This, of course, would not be recommended in combined sewer areas and is presented for cost information only.

TABLE B6
CONCRETE STORAGE COST

	2020 Volume (MG/YEAR)	Plant Capital ($1000)	Plant O&M ($1000/Yr)	Pipe Capital ($1000)	Pipe O&M ($1000/Yr)	Annual Compar. Value ($1000/Yr)
Plan #1 Concrete & Earth	86,693	784,540	4,309	348,646	2,179	92,330
Plan #1 All Concrete	86,693	1,752,900	5,377	348,646	2,179	160,395
Plan #1 All Earth	86,693	440,000	4,400	348,646	2,179	71,079

4.3 SENSITIVITY OF FLOW ADJUSTMENT ASSUMPTION

As discussed in Section 2.2, the peak flow and volume were adjusted for the institutional constraint of zoning. In order to show the potential benefit of the type of zoning, plans 1 and 2 were computed using the unadjusted flow rates and volumes. The results are shown in Table B7.

TABLE B7
UNADJUSTED VS. ADJUSTED FLOW COSTS

	2020 Volume (MG/Year)	Plant Capital ($1000)	Plant O&M ($1000/Yr)	Pipe Capital ($1000)	Pipe O & M ($1000/Yr)	Annual Compar. Value ($1000/Yr)
Plan #1 & #2 Unadjusted Flow	86,693	784,540	4,309	348,646	2,179	92,330
Plan #1 & #2 Adjusted Flow	74,254	747,886	3,718	345,824	2,156	88,683

4.4 COMPARISON OF LEVEL 1 AND LEVEL 2 LOADS TO RURAL RUNOFF

BOD and suspended solids loads from the urban area, both combined and separate, and the rural loads are compared to evaluate the significance of each source and reduction possible by treatment of the urban runoff. Comparing the rural load contribution to the urban load shows that 6.6% of the BOD and 28.3% of the suspended solid originates from the rural area.

Table B8 illustrates the net effect on stormwater BOD and suspended solids residuals as compared to the total stormwater runoff for the study area. Increasing the degree of treatment from Level 1 to Level 2 increases the BOD percent removal from 68 to 91 and the suspended solid percent removal from 63 to 71.

This is discussed further in Section 4.6 with respect to the total load from the study area.

TABLE B8

EFFECT OF TREATMENT ON STORMWATER RUNOFF

	1970 MG/Yr.	1970 %	2020 MG/Yr.	2020 %
VOLUMES				
Urban (Combined) Runoff	14,506	12	16,150	12
Urban (Separate) Runoff	20,949	19	65,561	51
Rural Runoff	78,668	69	49,515	37
Total Runoff	114,123	100	131,226	100

		2020 1000 lbs./Yr.	1000 lbs. Removed	1000 lbs. Residual	Percent of Total Removed	Percent of Total Residual
BOD						
	(Urban (Combined)	8,070	6,690	1,380	32	8
	(Urban (Separate)	11,099	7,390	3,709	36	18
Level 1	(Rural	1,341	0	1,341	0	6
	(Total	20,510	14,080	6,430	68	32
	(Urban (Combined)	8,070	7,908	162	38	0.8
	(Urban (Separate)	11,099	10,766	333	53	1.6
Level 2	(Rural	1,341	0	1,341	0	6.6
	(Total	20,510	18,674	1,836	91	9

		2020 1000 lbs./Yr.	1000 lbs. Removed	1000 lbs. Residual	Percent of Total Removed	Percent of Total Residual
SUSPENDED SOLIDS						
	(Urban (Combined)	26,908	22,871	4,037	7	2
	(Urban (Separate)	183,812	165,430	18,382	56	6
Level 1	(Rural	84,680	0	84,680	0	29
	(Total	295,400	188,302	107,099	63	37
	(Urban (Combined)	26,908	26,638	270	9	.1
	(Urban (Separate)	183,812	181,973	1,839	62	.6
Level 2	(Rural	84,680	0	84,680	0	28.3
	(Total	295,400	208,611	86,789	71	29

4.5 COST OF TREATING NON-SEPARABLE COMBINED SEWER OVERFLOWS

The plans 1 through 12 present cost data for runoff which does in fact include all runoff resulting from rainfall. These costs are not totally additive to municipal wastewater treatment cost since a part of this runoff is in combined sewered areas when the flows are mixed and the storm water is treated regardless of the scheme. In order to present the appropriate wastewater management cost, the combined sewer area cost has been separated from the total stormwater runoff cost. The flow from the combined sewer areas would be the first to receive treatment.

Table B9 shows the separation. Flows from each area are indicated and the total capital cost of constructing collection, storage, and treatment facilities are shown.

TABLE B9

COMBINED OVERFLOW COST

Plan	Level	Combined Overflow MG/Yr.	Separate Stormwater MG/Yr.	Total Capital Cost Combined $1,000,000	Total Capital Cost Separate $1,000,000
1	1	16,218	58,036	348	744
2	1	16,218	58,036	348	744
3	2	16,218	58,036	812	1,734
4	2	16,218	58,036	537	1,380
5	1	16,218	58,036	750	801
6	1	16,218	58,036	731	798
7	2	16,218	58,036	338	1,339
8	2	16,218	58,036	369	1,286
9A	2	16,218	58,036	555	1,791
10	2	16,218	58,036	812	1,734
11	2	16,218	58,036	768	1,709
12	2	16,218	58,036	388	1,049

4.6 COST OF INCREASED TREATMENT

The total annual cost of increasing treatment to meet the level 2 goals over level 1 is compared with the increase in pollutant residual mass loads. This data reflects the incremental removal using plan 1 which was designed both for level 1 and 2 goals.

TABLE B10

STORM WATER REMOVAL

Parameter	Total Removal of Level 1	Total Removal of Level 2	Incremental Removal of Level 2	Incremental Removal Cost of Level 2
Suspended Solids	84%	99%	15%	100%
BOD_5	65%	97%	32%	
Nitrogen, (Total)	54%	95%	41%	
Phosphorus	77%	94%	17%	

TABLE B11

MUNICIPAL WASTE

Parameter	Total Removal of Level 1	Total Removal of Level 2	Incremental Removal of Level 2	Incremental Removal Cost of Level 2
Suspended Solids	99%	99%	0%	43%
BOD_5	97%	99%	2%	
Nitrogen, (Total)	26%	97%	71%	
Phosphorus	96%	99%	3%	
COD	93%	98%	5%	

Table B12 shows the residual loads resulting from the two levels expressed in pounds per year and also as a percent of the total load. The rural loads are not treated. The urban load is the total from both the separate and combined sewered areas.

TABLE B12

RESIDUAL LOADS* 1,000 lbs/year

Parameters	Urban Runoff Level 1	Urban Runoff Level 2	Rural Runoff Level 1	Rural Runoff Level 2	Municipal Level 1	Municipal Level 2	Total Level 1	Total Level 2
Suspended Solids	22,419	2,109	84,680	84,680	4,838	879	111,937	87,668
BOD_5	5,089	495	1,341	1,341	12,046	860	18,476	2,696
Nitrogen, Total	1,496	163	825	825	41,901	1,689	44,222	2,677
Phosphorus	343	81	83	83	1,207	241	1,633	405

RESIDUAL LOADS, percent of total

Parameters	Urban Runoff Level 1	Urban Runoff Level 2	Rural Runoff Level 1	Rural Runoff Level 2	Municipal Level 1	Municipal Level 2	Total Level 1	Total Level 2
Suspended Solids	20	3	76	96	4	1	100	100
BOD_5	28	18	7	50	65	32	100	100
Nitrogen, Total	3	6	2	31	95	63	100	100
Phosphorus	21	20	5	20	74	60	100	100

*Total load discharged to receiving waters.

The incremental cost of treating storm water to Level 2 is primarily in the unit process concepts designed for soluble pollutant removal (i.e., organics, nitrogen and phosphorus), with additional suspended solids capture. Nitrogen in the storm and combined sewer runoff is an insignificant percentage of the total when compared to the municipal residual in both Level 1 and 2. The BOD residual, as shown in Table B12, is 36% of the total load when compared to Rural and Municipal, and the suspended solids is 20% of the total load. The suspended solids, although they are 20% of the load, would contain a high percentage of inert materials such as silt. Level 2 treatment reduces the BOD to 18% and Suspended Solids to 3% of the total load.

Comparing the residuals, it would appear that the benefit of treating storm water to Level 2 does not justify the incremental cost.

With municipal wastes, the incremental cost is primarily due to the unit process techniques required for nitrogen and COD removal. Nearly the total load of nitrogen is in the municipal waste and is reduced by 94% by the Level 2 treatment process over Level 1. If the removal of nitrogen can be scientifically shown to reduce the euthrophication of Lake Erie, then its removal should be considered. The incremental cost of Level 2 can be decreased by about 20%, if the COD requirement is reduced. The additional COD removed for this 20 percent cost increment is largely refractory or biologically inert. Thus, its immediate influence on the environment would be minimal whereas its long term affect is unknown. The necessity for this removal and the associated unit process should be weighed against, what are now, immeasurable future benefits.

C. ALTERNATIVE PLANS - COST ESTIMATES

1. - PROCEDURE

Twelve alternative plans have been developed for total wastewater management of the study area. These plans are described in detail by the Plan Formulators, Wright-McLaughlin Engineers, in their phase report and will not be duplicated here.

This section of the report presents the cost estimations of the twelve plans as related to our portion of the study. This portion is described in the following paragraphs. Plans 1 through 8 were computed to both Levels 1 and 2 in order to better evaluate the merits of the plans.

The procedure for the cost estimation include the calculation of the following items for each of the major segments involved.

1) Net capital cost - This cost is based on the 2020 design flows and takes into account the present worth of the existing structures.
2) Annual Capital - This cost is based on a capital recovery factor multiplied by the net capital cost. The capital recovery factor is a function of the useful life of the item and an interest rate of 7%.
3) Operation and Maintenance - This cost is based on the 2020 design flow of the particular segment.

2. - COMPARATIVE COST PRESENTATION

Havens and Emerson's portion of the alternative plans cost estimation is divided into four basic areas to better evaluate the relative features and costs of each plan. These areas include:

1) Wastewater Treatment Plants - Liquid Phase. Table C1 includes the cost breakdown for each plan as previously described for the liquid phase of the wastewater treatment plants and the pipe costs for the required interceptor systems. Of particular importance in the examination

of this table is that the cost fluctuations between plans is dependent upon the quantity of wastewater receiving secondary treatment and the quantity of wastewater receiving advanced treatment.

2) Wastewater Treatment Plants - Solid Phase. Table C2 includes the cost breakdown for each plan for the solid phase of the wastewater treatment plant. There are two important variations which explain the cost fluctuation between the plans. The first is that each plan has different combinations of the three techniques utilized for ultimate sludge disposal (incineration, agricultural application, strip mine reclamation). The second is that different quantities of sludge are being generated in each plan due to the differences in the levels of treatment.

3) Storm Water Treatment - Liquid Phase. Table C3 includes the cost breakdown for each plan for the liquid phase of stormwater treatment. There are four basic schemes of stormwater treatment which should be noted in the evaluation due to their significant effect on the cost fluctuations of the plans. The difference is largely due to the variation in volumes of storage required for each of these schemes. Scheme 1 requires storage of slightly less than the 1 year storm. Scheme 2 and 3 require storage of the 1 year storm. Scheme 4 requires storage of 20% of the annual runoff, which is the equivalent of the runoff resulting from a 100 year rainfall. Table C5 shows the actual storage volumes required for each plan. Following is a list of the four schemes:

1. Separate storm water treatment (Levels 1 and 2) with discharge to stream.
2. Storm water storage and treatment with discharge to land treatment.
3. Storm water storage only with discharge to land treatment. This was done for Plan 12 only.

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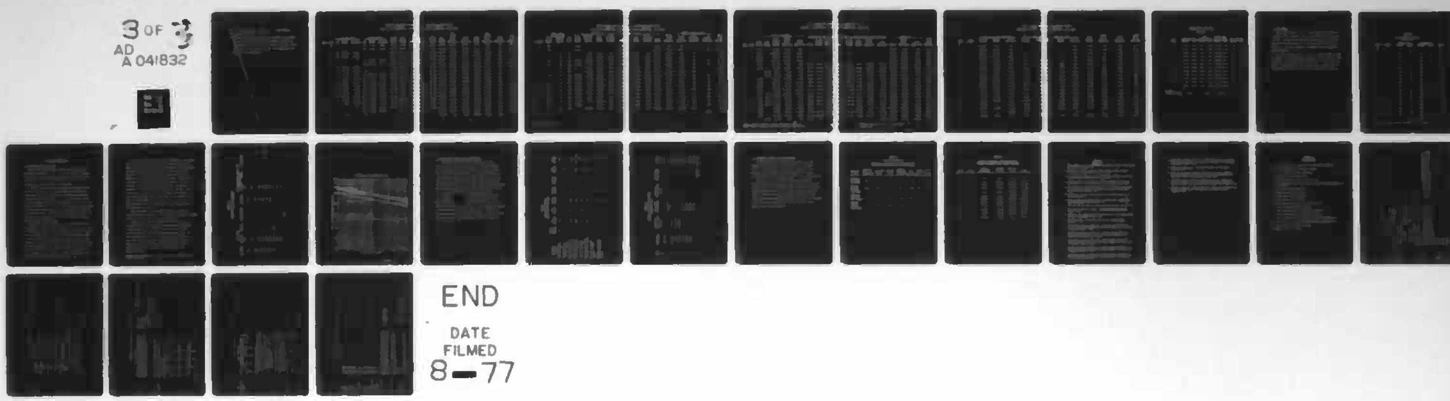

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4. Storm water storage with discharge to the sanitary system for treatment at the municipal plant.

Storm Water Treatment - Solid Phase Table C4 includes the cost breakdown for the solid phase of stormwater treatment. The quantity of sludge generated appears to be the most significant variable in causing cost fluctuations between the plans. This varies depending upon the method of stormwater treatment.

WASTEWATER MANAGEMENT PROGRAM
TABLE C1
WASTEWATER TREATMENT PLANT - LIQUID

		Secondary Plants			Advanced Plants					
Plan	Level	mgd	Capital ($1000)	O & M ($1000/Yr.)	mgd	Capital ($1000)	O & M ($1000/Yr.)	Present Worth ($1000)	Net Capital ($1000)	Pl An Capi Co ($100
1	1	-	-	-	794	404,236	43,507	156,066	248,170	19,1
1	2	-	-	-	794	595,586	59,628	156,066	439,520	33,9
2	1	794	368,967	23,014	-	-	-	169,566	197,401	15,2
2	2	794	368,967	23,014	-	-	-	169,566	197,401	15,2
3	1	-	-	-	794	418,610	46,481	167,825	250,785	19,3
3	2	-	-	-	794	625,898	62,615	167,825	458,073	35,4
4	1	794	370,701	23,082	-	-	-	169,566	201,135	15,5
4	2	794	370,701	23,082	-	-	-	169,566	201,135	15,5
5	1	26	24,007	1,736	768	395,224	43,659	170,066	249,165	19,2
5	2	26	24,007	1,736	768	565,587	63,854	170,066	419,628	32,3
6	1	393	196,409	12,933	401	195,792	21,211	173,931	218,270	16,8
6	2	393	196,409	12,933	401	310,065	29,159	173,931	332,543	25,
7	1	26	23,617	1,702	768	402,743	47,400	162,933	263,427	20,
7	2	26	23,617	1,702	768	564,027	56,690	162,933	424,711	32,
8	1	600	283,276	18,290	194	96,100	10,846	169,541	209,835	16,
8	2	600	283,276	18,290	194	146,080	13,979	169,541	259,815	20,
9A	2	328	1,420	1,198	466	332,500	32,633	92,695	241,225	18,
10	2	-	-	-	794	625,898	62,615	167,825	458,073	35,
11	2	-	-	-	794	389,124	76,503	-	389,124	33,
12	2	794	4,478	-	-	-	-	-	4,478	

1

WASTEWATER MANAGEMENT PROGRAM
TABLE C1
WASTEWATER TREATMENT PLANT - LIQUID PHASE

ts O & M 000/Yr.)	Present Worth ($1000)	Net Capital ($1000)	Plant Annual Capital Cost ($1000/Yr.)	Total O & M ($1000/Yr.)	Sewer Capital ($1000)	Sewer Annual Capital Cost ($1000/Yr.)	Sewer O & M ($1000/Yr.)	Annual Compar. Value ($1000/Yr.)
43,507	156,066	248,170	19,159	43,507	69,310	5,024	440	68,130
59,628	156,066	439,520	33,930	59,628	69,310	5,024	440	99,022
-	169,566	197,401	15,239	23,014	65,099	4,720	359	43,332
-	169,566	197,401	15,239	23,014	65,099	4,720	359	43,332
46,481	167,825	250,785	19,360	46,481	75,039	5,440	436	71,717
62,615	167,825	458,073	35,400	62,615	75,039	5,440	436	103,891
-	169,566	201,135	15,528	23,082	65,099	4,720	372	43,702
-	169,566	201,135	15,528	23,082	65,099	4,720	372	43,702
43,659	170,066	249,165	19,236	45,395	67,507	4,894	422	69,947
63,854	170,066	419,628	32,395	65,590	67,507	4,894	422	103,301
21,211	173,931	218,270	16,850	34,144	67,507	4,894	422	56,310
29,159	173,931	332,543	25,672	42,092	67,507	4,894	422	73,080
47,400	162,933	263,427	20,336	49,142	74,218	5,381	463	75,322
56,690	162,933	424,711	32,788	58,392	74,218	5,381	463	97,024
10,846	169,541	209,835	16,199	29,136	65,779	4,769	373	50,477
13,979	169,541	259,815	20,058	34,269	65,779	4,769	373	59,469
32,633	92,695	241,225	18,623	33,831	82,754	6,000	548	59,002
62,615	167,825	458,073	35,363	62,615	75,046	5,440	436	103,854
76,503	-	389,124	33,386	76,503	74,969	5,435	436	115,760
-	-	4,478	346	1,248	65,099	4,720	406	6,720

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WASTEWATER MANAGEMENT PROGRAM
TABLE C2
WASTEWATER TREATMENT PLANT - SOLID

		Sludge Volumes Dry Tons/Day			Capital Cost				
Plan	Level	Inciner-ation	Agricultural Application	Strip Mines	Inciner-ation ($1000)	Agricultural Application ($1000)	Strip Mines ($1000)	Pump Station & Force Main ($1000)	Total ($1000)
1	1	835	-	-	64,360	-	-	-	64,360
1	2	926	-	-	68,134	-	-	-	68,134
2	1	-	34	477	-	6,572	40,758	7,924	55,254
2	2	-	34	477	-	6,572	40,758	7,924	55,254
3	1	464	78	299	29,900	10,852	25,180	2,359	68,291
3	2	515	86	330	31,700	11,670	26,710	2,359	72,439
4	1	-	34	477	-	6,572	40,758	7,924	55,254
4	2	-	34	477	-	6,572	40,758	7,294	55,254
5	1	376	31	424	35,675	5,205	33,500	2,408	76,788
5	2	413	31	466	37,600	5,355	38,050	2,408	83,313
6	1	247	41	393	18,250	7,705	30,858	3,307	60,120
6	2	272	41	410	19,250	7,705	36,590	3,307	66,852
7	1	372	13	440	30,500	3,325	36,000	2,875	72,700
7	2	411	13	491	32,450	3,325	40,050	2,875	78,700
8	1	264	28	315	20,350	5,105	26,810	4,130	56,395
8	2	284	28	316	21,050	5,105	27,010	4,130	57,305
9	2	317	-	377	20,700	-	20,000	1,097	41,797
10	2	-	386	537	-	31,880	35,915	7,197	74,992
11	2	-	-	-	-	-	-	-	-
12*	2	-	-	-	-	-	-	-	-

*Preliminary Treatment Only

WASTEWATER MANAGEMENT PROGRAM
TABLE C2
WASTEWATER TREATMENT PLANT - SOLID PHASE

Capital Cost				Operation and Maintenance			
Strip Mines ($1000)	Pump Station & Force Main ($1000)	Total ($1000)	Annual Capital Cost ($1000/Yr.)	Capital Fac. ($1000/Yr.)	Pump Station & Force Main ($1000/Yr.)	Ash Disposal ($1000/Yr.)	Annual Compar. Value ($1000/Yr.)
-	-	64,360	4,969	9,438	-	405	14,811
-	-	68,134	5,260	10,152	-	667	16,079
40,758	7,924	55,254	4,266	1,499	470	-	6,235
40,758	7,924	55,254	4,266	1,499	470	-	6,235
25,180	2,359	68,291	5,272	6,038	142	357	11,809
26,710	2,359	72,439	5,590	6,533	142	393	12,658
40,758	7,924	55,254	4,266	1,499	470	-	6,235
40,758	7,294	55,254	4,266	1,499	470	-	6,235
33,500	2,408	76,788	5,928	5,718	145	289	12,080
38,050	2,408	83,313	6,431	6,110	145	316	13,002
30,858	3,307	60,120	4,641	4,261	184	187	9,273
36,590	3,307	66,852	5,160	4,577	184	206	10,127
36,000	2,875	72,700	5,612	5,229	173	284	11,298
40,050	2,875	78,700	6,076	5,622	173	314	12,185
26,810	4,130	56,395	4,354	4,037	248	201	8,840
27,010	4,130	57,305	4,424	4,189	248	217	9,078
20,000	1,097	41,797	3,227	3,564	66	243	7,100
35,915	7,197	74,992	5,789	3,443	425	-	9,657
-	-	-	-	-	-	1,494	1,494
-	-	-	-	-	-	-	-

WASTEWATER MANAGEMENT PROGRAM
TABLE C3
STORMWATER TREATMENT PLANT - LIQUID

		Separate Treatment					Stormwater to Municipal P		
Plan	Level	ASWTP[1] MG/Yr.	SWTP[2] MG/Yr.	Plant + Storage Capital ($1000)	Plant Annual Capital Cost ($1000/Yr.)	Plant O & M ($1000/Yr.)	MG/Yr.	Storage Capital ($1000)	Plant Capital ($1000)
1	1	74,254	-	747,886	57,737	3,718	-	-	-
1	2	74,254	-	1,306,500	100,861	21,816	-	-	-
2	1	74,254	-	747,886	57,737	3,718	-	-	-
2	2	74,254	-	1,306,500	100,861	21,816	-	-	-
3	1	9,704	-	122,250	9,437	536	65,072	1,811,986	110,272
3	2	9,704	-	197,300	15,232	4,260	65,072	1,811,986	163,856
4	1	-	18,061	50,972	3,935	801	55,711	1,475,205	112,933
4	2	-	18,061	50,972	3,935	801	55,711	1,475,205	112,933
5	1	57,546	-	533,150	41,160	2,749	15,492	775,190	21,110
5	2	57,546	-	875,009	67,550	16,256	15,492	775,190	31,600
6	1	58,085	-	543,021	41,921	2,749	16,111	670,840	18,799
6	2	58,085	-	875,009	67,550	16,256	16,111	670,840	29,735
7	1	32,712	3,125	266,870	26,304	1,909	38,345	872,515	44,211
7	2	32,712	3,125	386,870	29,866	7,770	38,345	872,515	59,861
8	1	7,617	32,541	369,163	26,764	2,316	33,053	837,605	46,050
8	2	7,617	32,541	410,248	31,677	3,998	33,053	837,605	52,385
9	2	5,463	-	117,800	9,094	2,049	69,404	3*	103,380
10	2	9,704	-	197,300	15,232	4,260	65,072	1,811,980	163,856
11	2	9,704	-	197,300	15,232	4,260	65,072	1,811,980	95,063
12	2	-	25,613	11,222[4]	866	696	48,530	3*	-

1

[1] ASWTP - Separate Stormwater Treatment Discharging to Waterway
[2] SWTP - Separate Stormwater Treatment Discharging to Land Treatment

[3] Sto
[4] Sto

STEWATER MANAGEMENT PROGRAM
TABLE C3
ER TREATMENT PLANT - LIQUID PHASE

Stormwater to Municipal Plants Combined Treatment					Pipe Cost			
G/Yr.	Storage Capital ($1000)	Plant Capital ($1000)	Annual Capital Cost ($1000/Yr.)	O & M ($1000/Yr.)	Capital	Annual Capital Cost ($1000/Yr.)	O & M ($1000/Yr.)	Annual Compar. Value ($1000/Yr.)
-	-	-	-	-	345,824	25,072	2,156	88,683
-	-	-	-	-	345,824	25,072	2,156	149,905
-	-	-	-	-	345,824	25,072	2,156	88,683
-	-	-	-	-	345,824	25,072	2,156	149,905
65,072	1,811,986	110,272	139,362	24,441	372,247	26,987	2,286	203,049
65,072	1,811,986	163,856	144,017	27,694	372,247	26,987	2,286	220,476
55,711	1,475,205	112,933	115,670	14,243	278,000	20,155	1,737	156,541
55,711	1,475,205	112,933	115,670	14,243	278,000	20,155	1,737	156,541
15,492	775,190	21,110	57,830	5,511	222,000	16,095	1,390	124,735
15,492	775,190	31,600	58,640	7,940	236,663	17,158	1,479	169,023
16,111	670,840	18,799	50,088	5,931	297,000	21,532	1,885	124,106
16,111	670,840	29,735	50,930	6,347	304,143	22,050	1,901	165,034
38,345	872,515	44,211	66,670	13,702	357,249	25,900	2,233	136,718
38,345	872,515	59,861	67,879	16,169	358,000	25,955	2,238	149,877
33,053	837,605	46,050	64,281	10,134	354,000	25,660	2,216	131,376
33,053	837,605	52,385	64,770	10,800	354,000	25,665	2,216	139,120
69,404	3*	103,380	7,981	13,427	2,125,407	154,092	11,768	198,411
65,072	1,811,980	163,856	144,017	27,694	372,247	26,987	2,286	220,476
65,072	1,811,980	95,063	138,706	26,827	372,247	26,987	2,286	214,298
48,530	3*	-	-	2,720	1,425,931	103,380	7,466	115,128

[3] Storage Capital Included in Pipe Capital Figure
[4] Storage Only

2

WASTEWATER MANAGEMENT
TABLE C4
STORMWATER TREATMENT PLANT

Plan	Level	Sedimentation and Storage Sludge: Dry Tons Per Year	Sedimentation and Storage Sludge: Capital ($1000)	Sedimentation and Storage Sludge: O & M ($1000/Yr.)	Treatment: Dry Tons Per Year	Treatment: Capital ($1000)
1	1	124,067	27,293	2,225	-	-
1	2	206,376	31,335	2,884	-	-
2	1	124,067	27,293	2,225	-	-
2	2	206,376	31,335	2,884	-	-
3	1	76,493	18,790	1,124	8,190	10,950
3	2	124,321	23,020	1,166	8,190	10,950
4	1	60,124	4,760	1,694	31,117	10,215
4	2	86,107	5,800	1,904	31,117	10,215
5	1	120,226	30,560	2,253	11,174	5,060
5	2	200,034	37,945	2,943	1,967	5,060
6	1	120,226	30,560	2,253	11,174	5,060
6	2	200,034	37,945	2,943	1,967	5,060
7	1	80,737	11,900	2,024	22,262	9,980
7	2	115,359	14,630	2,755	22,262	9,980
8	1	81,138	15,920	1,303	3,983	7,930
8	2	138,140	20,830	1,577	3,983	7,930
9A	2	95,865	-	3,393	17,845	10,360
10	2	124,321	18,695	1,166	8,190	10,075
11	2	124,321	-	1,166	8,190	-
12	2	98,831	5,800	2,343	31,117	10,115

1

WATER MANAGEMENT PROGRAM
TABLE C4
TREATMENT PLANT - SOLID PHASE

	Treatment Sludge					
ons ear	Capital ($1000)	O & M ($1000/Yr.)	Total Capital ($1000)	Annual Capital Cost ($1000/Yr.)	Total O & M ($1000/Yr.)	Annual Compar. Value ($1000/Yr.)
	-	3,141	27,293	2,107	5,302	7,409
	-	4,900	31,335	2,419	7,784	10,203
	-	3,141	27,293	2,107	5,302	7,409
	-	4,900	31,335	2,419	7,784	10,203
90	10,950	3,265	29,740	2,295	4,389	6,684
90	10,950	4,722	34,810	2,687	5,880	8,567
17	10,215	1,995	14,975	1,156	3,689	4,845
17	10,215	2,422	16,015	1,236	4,326	5,562
74	5,060	3,898	35,620	2,750	6,151	8,901
67	5,060	5,429	43,005	3,319	8,372	11,691
74	5,060	3,898	35,620	2,750	6,151	8,901
67	5,060	5,429	43,005	3,319	8,372	11,691
62	9,980	2,517	21,880	1,689	4,541	6,230
62	9,980	2,770	24,610	1,900	5,525	7,425
83	7,930	3,110	23,850	1,841	4,413	6,254
83	7,930	4,562	28,760	2,220	6,139	8,359
45	10,360	1,283	10,360	800	4,676	5,476
90	10,075	3,651	28,770	2,221	4,817	7,038
90	-	43	-	-	1,209	1,209
17	10,115	2,422	16,015	1,236	4,765	6,001

2

CONCRETE/EARTH BREAKDOWNS

TABLE C5

Plan	Volume (mg/yr)		(mg) Storage Volume		Capital Cost Storage ($1000)		No. of Basins	
	Concrete	Earth	Concrete	Earth	Concrete	Earth	Concrete	Earth
1	41,107	33,389	2,815	2,310	427,995	24,414	36	97
2	41,107	33,389	2,815	2,310	427,995	24,414	36	97
3	41,267	32,697	7,813	6,176	1,879,030	32,479	38	98
4	40,577	32,993	7,206	5,078	1,485,840	25,216	35	91
5	39,574	34,489	4,105	2,918	958,080	23,531	33	98
6	39,574	34,489	4,105	2,918	958,080	23,531	33	98
7*	34,197	29,926	4,283	4,837	1,042,300	27,083	37	94
8	42,468	31,060	3,990	4,627	982,705	26,466	39	88
9	41,800	31,120	7,626	6,224	1,640,070	29,415	48	74
10	41,267	32,697	7,813	6,176	1,879,030	32,479	38	98
11	41,267	32,697	7,813	6,176	1,879,030	32,479	38	98
12	40,577	32,993	7,206	5,078	1,261,130	25,216	35	91
*Easterly Off-Shore Storage	9,107		1,821		5,000		1	

3. - COST SUMMARY

Table C6 summarizes the costs for Plans 1 through 12 as developed for the wastewater and stormwater portions of the cost estimation as previously described. It should be noted again that the cost summaries as presented here are not the entire plan costs in that they include no cost for land treatment of wastewater, stormwater, or sludge and no cost for industrial waste pretreatment.

It should be further noted that with Plan 11, there has been no attempt to consider the outstanding bonded indebtedness of existing plants that would be abandoned. This would increase the annual cost. The Plan 11, physical-chemical, cost estimates do not have the same degree of reliability as the biological systems since the history of actual construction cost is limited.

TABLE C6

ANNUAL COMPARITIVE VALUES*
($1,000,000/Yr)

Plan	Level	Wastewater Liquid	Wastewater Solid	Stormwater Liquid	Stormwater Solid	TOTAL
1	1	68	15	87	7	177
1	2	99	16	143	10	268
2	1	43	6	87	7	143
2	2	43	6	143	10	212
3	1	72	12	203	7	294
3	2	104	13	220	9	346
4	1	44	6	157	5	212
4	2	44	6	157	6	213
5	1	70	12	125	9	216
5	2	103	13	169	12	297
6	1	56	9	124	9	198
6	2	73	10	165	12	260
7	1	75	11	137	6	229
7	2	97	12	150	7	266
8	1	50	9	131	6	196
8	2	59	9	139	8	215
9	2	59	7	198	5	269
10	2	104	10	220	7	341
11	2	116	1	214	1	332
12	2	7	-	115	6	128

*These costs include no costs associated with land treatment.

D - RELATED INFORMATION

1. ELECTRICAL POWER REQUIREMENTS

The electric power requirements needed to treat a given volume of wastewater were obtained from Figure D1. Four basic plots are included in this figure. These represent power requirements per million gallons of wastewater for primary and secondary treatment, state goals (Level 1), federal goals (Level 2) and aeration for pre-treatment.

In computing values for plotting the primary and secondary treatment curve, the electric power requirement was computed for treatment plants having a wide range of average plant flows. The ratio of kilowatt-hours to million gallons treated was computed for these various plants initially for only the diffused, single-stage aeration assuming 1.5 cubic feet of air required per gallon, 25 cubic feet of air produced per minute per horsepower and the conversion from horsepower to kilowatts (taking into consideration motor efficiencies, etc.). The power required for the aeration process was then assumed to be approximately 60% of the total KWH/MG for primary and secondary treatment excluding pumping.

Computation of power requirements for state goals (Level 1) includes power consumed in primary treatment, aeration and by the use of microstrainers. Five horsepower is needed for every 10 MGD for the microstrainers. Aeration, which is a combination of 0.7 cu.ft./gal. for high rate activated sludge, 1.5 cu.ft./gal. for nitrifying activated sludge, and 0.1 cu.ft./gal. for post-aeration, requires a direct ratio of cu.ft./gal. to the power required for the aeration process of the primary-secondary process. Here, 2.3 cu.ft. of air per gallon is required compared to 1.5 cu.ft. per gallon of the primary-secondary process. Power for the primary treatment process is the same as the previous power requirements for this process.

O.C.E. goal (Level 2) treatment power requirements are a combination of electric power used for carbon adsorption, aeration, denitrification mixing, and primary treatment. The power requirement for carbon adsorption is based on a total dynamic head of 20 feet and the conversion from horsepower to kilowatts. Primary treatment requires 40% of the power required for the combined primary and secondary process. Aeration, which is a combination of high rate activated sludge aeration (.7 cu.ft./gal.), nitrifying activated sludge aeration (1.5 cu.ft./gal.), denitrifying reaeration (0.1 cu.ft./gal.), and post-aeration (0.1 cu.ft./gal.), requires a direct ratio of cu.ft./gal. to the power required for the aeration process of the primary-secondary process. Here, 2.4 cubic feet of air per gallon is required compared to the 1.5 cubic feet per gallon of the primary-secondary process. Five horsepower is required per MGD for the denitrification mixing process.

Power requirements for pre-treatment aeration is a constant 700 kilowatt-hours per million gallons. This is obtained by assuming an electrical power cost of $7/MG at a rate of 1.21¢ per kilowatt-hour.

Using Figure D1*, the power required for each plan was computed. The average plant size for each particular plan was entered onto the abscissa of Figure D1 and the power requirement in kilowatt-hours per million gallons was read off the curve of the appropriate treatment level. This power requirement (KWH/MG) was then multiplied by the total flow for each plan for the total power required. The power required for each plan is summarized on Table D1. The total cost for power for each plan can be computed by multiplying 1.21¢/KWH times the power required in the aforementioned table.

*Federal Goals refer to standards established by O.C.E. (Office of the Chief of Engineers).

TABLE D1

ELECTRICAL POWER REQUIREMENTS

	FLOW (MGD)				POWER REQUIREMENTS (MEGAW/DAY) TYPE OF PLANT			
	Secondary	Tertiary	Primary	Pre-Treatment	Secondary	Tertiary	Primary	Pre-Treatment
1		794				2040		
2	794				1730			
3		794				2460		
4	794				1730			
5	26	768			91	2700		
6	393	401			965	961		
7	26	768			91	2080		
8	600	194			1380	520		
9	8	458	318		25	1140	35	
10		794				2460		
11		794				2460		
12				794				557

ELECTRIC POWER REQUIREMENTS

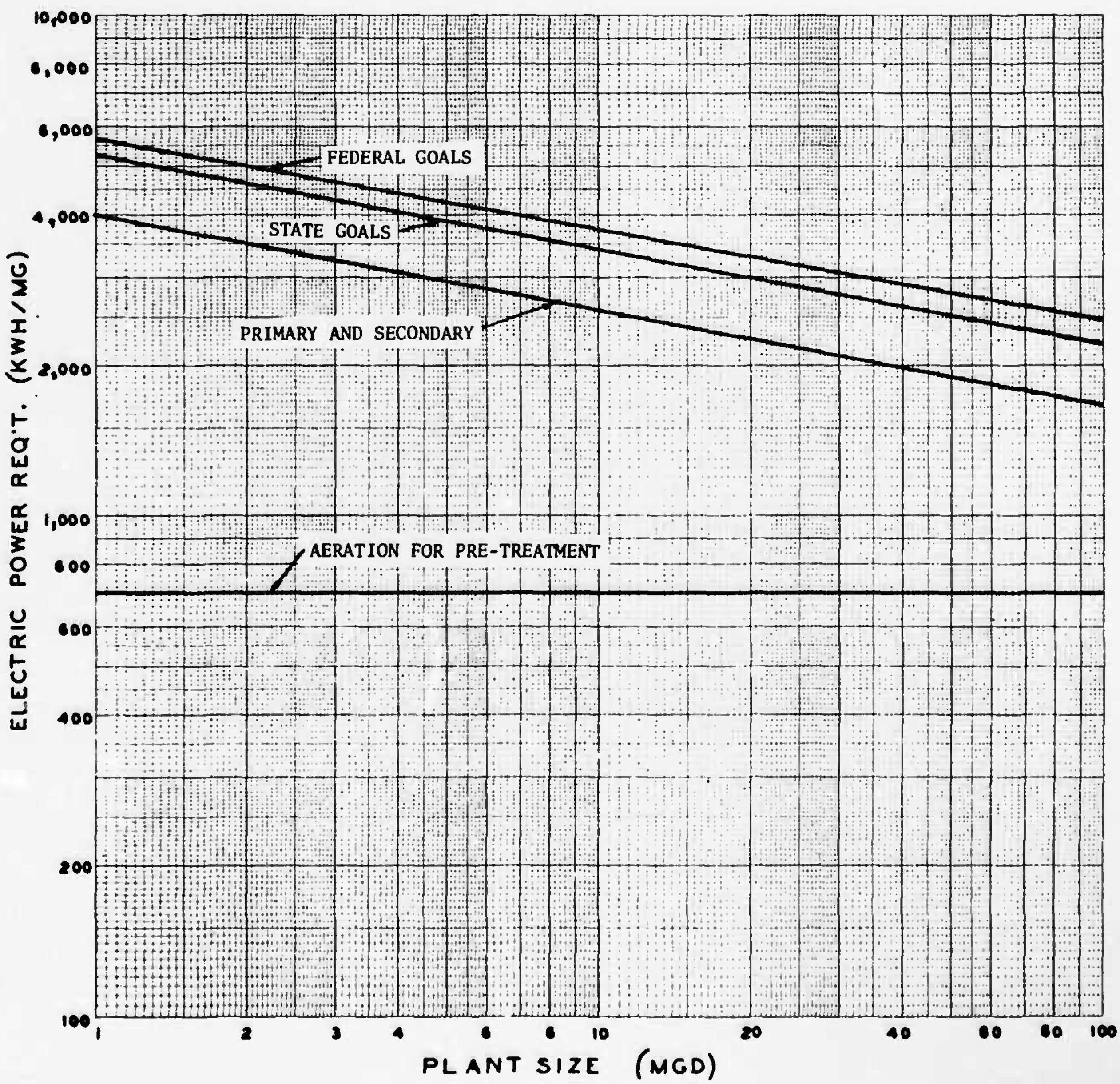

FIGURE D1

2. WASTEWATER TREATMENT CHEMICAL REQUIREMENTS

A breakdown of the daily chemical requirements for various treatment processes is summarized on Table D2. Chemicals needed for both the biological and physical-chemical treatment systems are shown for a basic system, state goals (Level 1), O.C.E. goals (Level 2), and the ultimate reuse applications. Each chemical additive is broken down into a requirement in pounds per day as taken from the mass balance diagrams for each process. The more stringent goals require more chemicals for both treatment systems while the physical-chemical process requires from 2 to 4 times as many chemicals as the biological process.

Table D3 illu[illegible] [illegible]ical requirements necessary for each type of treatment [illegible] r plan for wastewater only. Plans meeting federal goals [illegible] the most chemicals except where physical-chemical treatment is utilized as in Plan 11. Plan 12 requires no chemicals since it only involves the pre-treatment processes. The values for Table D3 were obtained by multiplying the total flow in each plan for each distinct process by the total requirements needed in that process as shown on Table D2.

TABLE D2

CHEMICAL REQUIREMENTS

(pounds per day per mgd)

Treatment Process	Lime & $FeCl_3$ (#/day)	Cl_2 (#/day)	Al^{+3} (#/day)	$Ca(OH)_2$ (#/day)	Polymer (#/day)	Methanol (#/day)	CaO (#/day)	Total (#/day)
Basic Biological Treatment System	70	66	-	-	-	-	-	136
Basic Phys-Chem Treatment System	-	-	-	-	14	-	720	734
Basic Bio. Treatment System (State Goals)	-	50	111	420	3	-	-	584
Basic Phys-Chem Treatment Sys. (S. Goals)	-	860	-	500	13	-	1050	2423
Basic Bio. Treatment System (Fed. Goals)	-	33	122	470	3	420	-	1048
Basic Phys-Chem Treatment Sys. (Fed. Goals)	-	860	-	500	13	-	1050	2423
Basic Bio. Treatment System (Ultimate Reuse)	-	33	122	470	3	420	-	1048
Basic Phys-Chem Treatment Sys. (Ultimate Reuse)	-	860	-	500	13	-	1050	2423

TABLE D3

CHEMICAL REQUIREMENTS PER PLAN

(pounds per day)

Plan	Secondary	Biological (State Goals)	Biological (Fed. Goals)	Phys-Chem (State Goals)	Phys-Chem (OCE. Goals)	Totals
1	-	425,000	-	49,400	-	474,400
2	118,000	-	-	-	-	118,000
3	-	-	833,000	-	-	833,000
4	118,000	-	-	-	-	118,000
5	3,540	442,000	-	-	-	445,540
6	53,500	234,000	-	-	-	287,500
7	3,540	-	805,000	-	-	808,540
8	81,600	-	203,500	-	-	285,100
9	44,600	-	488,000	-	-	532,600
10	-	-	833,000	-	-	833,000
11	-	-	-	-	1,925,000	1,925,000
12	-	-	-	-	-	-

3. STORMWATER TREATMENT CHEMICAL REQUIREMENTS

The chemicals required for treatment of stormwater runoff and combined sewer overflows are illustrated in Table D4. State goals (Level 1) require no chemicals for both types of flows while it is necessary to use 872 #/MG and 2310 #/MG of chemicals for stormwater runoff and combined sewer overflows respectively for O.C.E. goals (Level 2).

Table D5, which is a breakdown of chemical requirements per plan for stormwater and combined sewer overflow treatment, was formulated by multiplying the total requirements in #/MG in Table D4 for the various treatment processes by the flow in each plan for each distinct process. Plan 11 requires the most chemicals because of the physical-chemical treatment involved in municipal plant treatment while Plans 1 and 2 require no chemicals since all treatment meets only State goals without any municipal plants handling stormwater.

TABLE D4

- CHEMICAL REQUIREMENTS -

STORMWATER & COMBINED SEWER OVERFLOW TREATMENT

TREATMENT PROCESS	POWDERED ACTIVATED CARBON (#/MG)	ALUM (AL^{+3}) (#/MG)	POLYMER (#/MG)	GRANULAR ACTIVATED CARBON (#/MG)	CL_2 (#/MG)	$CA(OH)_2$ (#/MG)	TOTAL (#/MG)
STORMWATER TREATMENT (OCE GOALS)	830	8	8	26	———	———	872
COMBINED OVERFLOW TREATMENT (OCE GOALS)	1000	100	4	26	430	750	2310
STORMWATER TREATMENT (STATE GOALS)	———	———	———	———	———	———	0
COMBINED OVERFLOW TREATMENT (STATE GOALS)	———	———	———	———	———	———	0

TABLE D5

CHEMICAL REQUIREMENTS (#/DAY) PER PLAN FOR STORMWATER & COMBINED SEWER OVERFLOW TREATMENT

PLAN	LEVEL	SEPARATE STORMWATER	COMBINED OVERFLOW	MUNICIPAL PLANT	TOTAL
1	1	——	——	——	0
2	1	——	——	——	0
3	2	6,170	45,500	187,000	238,670
4	2	26,200	45,500	20,800	92,500
5	1	——	——	24,560	24,560
6	1	——	——	8,980	8,980
7	2	68,500	45,500	106,500	220,500
8	2	65,500	80,000	46,650	192,150
9	2	8,150	13,000	126,190	147,340
10	2	6,170	45,500	187,000	238,670
11	2	6,170	45,500	434,500	486,170
12	2	51,500	4,070	——	55,570

APPENDIX A
REFERENCES

1. Smith, Robert, "Cost of Conventional and Advanced Treatment of Wastewater", Journal WPCF, September 1968.

2. Federal Water Pollution Control Administration, "A Study of Sludge Handling and Disposal", (PC-20-4), April, 1968.

3. Environmental Protection Agency, "Advanced Waste Treatment as Practiced at South Tahoe", (WPRD 52-01-67), August, 1971.

4. Burgess & Niple, Ltd., "Project Cost Study" for Northeast Ohio Water Development Plan, Ohio Department of Natural Resources, June, 1970.

5. Black & Veatch, "Preliminary, Estimating Cost and Manpower Requirements for Conventional Wastewater Pretreatment Facilities," Environmental Protection Agency, October, 1971.

6. Confidential data from various manufacturers representatives on past and future projects.

7. Dryden, Franklin, "Demineralization of Reclaimed Water", Industrial Waste Engineering, August/September, 1971.

8. Cost data from bid sheets on previous Havens and Emerson, Ltd. projects.

9. Culp, Russel L. and Culp, Gorden L., Advanced Wastewater Treatment, January, 1971.

10. Mulbarger, M.C., "Nitrification and Denitrification in Activated Sludge Systems", Journal WPCF, October, 1971.

11. "Ozone Adds Punch to Oxidation of Wastewaters", Chemical Week, November 3, 1971.

12. Environmental Quality Systems, Inc., "Preliminary Technical Review of Activated Carbon Treatment Costs and Effectiveness", U.S. Army Corps of Engineers, March 1, 1972.

13. Environmental Quality Systems, Inc., "Interim Technical Review of Electrodialysis and Reverse Osmosis Costs and Effectiveness", U.S. Army Corps of Engineers, May 1, 1972.

14. Environmental Quality Systems, Inc., "Interim Technical Review of Biological Nitrogen Removal Costs and Effectiveness", U.S. Army Corps of Engineers, March 31, 1972.

15. Environmental Quality Systems, Inc., "Interim Technical Review of Chemical Phosphorus Removal Costs and Effectiveness", U.S. Army Corps of Engineers, March 17, 1972.

16. Environmental Quality Systems, Inc., "Interim Technical Review of Selected Filtration Process Costs and Effectiveness", U.S. Army Corps of Engineers, March 10, 1972.

17. Environmental Quality Systems, Inc., "Technical Note on the Occurrence of Viruses in Wastewater and Disinfection Procedures", U.S. Army Corps of Engineers, June 1, 1972.

18. Stanley Consultants, Inc., "Wastewater Treatment Unit Processes, Estimating Costs, 1972."

19. Office of the Chief of Engineers, Department of the Army, "Regional Wastewater Management Systems for the Chicago Metropolitan Area, Cost Data Annex to the Technical Appendix", March, 1972.

20. Dalton-Dalton-Little, Resource Engineering Associates, "Program for the Lower Cuyahoga River", Industrial Waste Survey for Department of Public Utilities, Clean Water Task Force, Cleveland, Ohio, January, 1971.

21. Burgess & Niple, Ltd., "Design Criteria for Northeast and Southwest Ohio Water Development Plans", Ohio Department of Natural Resources, September, 1971.

APPENDIX B
PLANNING INPUT

During the course of this study, the following people, firms, and agencies were contacted for information or input.

1. Tri County Regional Planning Commission.
2. Geauga County Planning Commission.
3. Department of Natural Resources, State of Ohio.
4. Mr. George Garrett, Department of Health, Division of Sanitary Engineering, State of Ohio.
5. Three Rivers Watershed District.
6. Geauga County Sanitary Engineers.
7. Portage County Sanitary Engineers.
8. Medina County Sanitary Engineers.
9. County Sanitary Engineers, Group of Northeast Ohio.
10. Burgess and Niple, Consulting Engineers.
11. Willard Schade and Associates, Consulting Engineers.
12. Alden Stilson and Associates, Consulting Engineers.
13. Berlie L. Schmidt, Ohio Agricultural Research and Development Center.
14. James M. Beattie, Ohio Agricultural Research and Development Center.
15. Michael Benza, Jr., Consulting Engineer.
16. Lewis DeBevec, City of Akron.

APPENDIX C: DISCHARGE REQUIREMENTS TO SURFACE WATERS

Item	Goal I - State of Ohio	Goal II - Federal Government
Settleable Solids	Substantially complete removal - monthly ave. 0.3 ml/1; max. 1.0 ml/1	Trace
Oils (and grease)	Lowest practical level attainable by today's technology; monthly ave. 10 mg/1; max. 20 mg/1	Trace
Debris, Scum, Flotables	Substantially complete removal	None
Suspended Solids (Inert)	Reduction to such a degree as to not cause noticeable turbidity in the receiving stream, but shall not exceed: Free Flowing Warm Water Fisheries: Monthly Ave. 30 mg/1, Maximum Daily 45 mg/1; Cold Water Fisheries, Pooling Streams, Scenic Rivers, Reservoirs and Inland Lakes: Monthly Ave. 20 mg/1, Maximum Daily 30 mg/1	< 5 mg/1
Color	Effluent imparts no objectionable color nor increases the background level by 5 standard units.	< 75 Color Units
Taste and Odor	Reduction to such a degree as to not cause an objectionable odor, a threshold odor number 724 to potable water supplies, nor cause fish flesh tainting.	Non Offensive
"Toxic" Constituents and Heavy Metals	Reduction of any and all materials to such a degree that the concentration thereof, singly or in combinations, in any discharge is not harmful to human health or aquatic life to such a degree that the concentration thereof in the discharge does not kill 25%+ of a mixed fish population common to the receiving stream in a 1:1 dilution of the sample with waters of the receiving stream provided that the calculated concentration in the receiving stream does not exceed 1/20 of the 96 hour median tolerance level.	Critical levels for all constituents not specifically mentioned shall be based upon natural background levels of the receiving watercourse or aquifer with exception of constituents that are highly toxic or injurious to the environment at trace levels. If current State water quality standards are higher, these standards shall apply; or levels of nontoxic constituents may be relaxed upward (above background levels) should they be proven to be not injurious to the environment of the region.
Arsenic	0.05 mg/1	Absent (not detectable by standard methods and current technology)
Barium	1.0 mg/1	"
Cadmium	0.01 mg/1	"
Chromium (hex.)	0.05 mg/1	"
Chromium (tot.)	0.30 mg/1	"
Copper	1.0 mg/1	"
Iron (total)	5.0 mg/1	No Comment
(soluble)	0.3 mg/1	"
Lead	0.05 mg/1	Absent
Mercury	0.005 mg/1	"
Nickel	0.01 mg/1	"
Silver	0.05 mg/1	"
Zinc	5.0 mg/1	"

APPENDIX C: DISCHARGE REQUIREMENTS TO SURFACE WATERS (CONT'D.)

Item	Goal I - State of Ohio	Goal II - Federal Government
Phosphorus	See below	
Temperature	See below	$< \pm$ 1°C. (1.8°F.) of ambient water temperature
[illegible]ity	No Comment	$<$ 5 Jackson Units

Phosphorus (Goal I - State of Ohio)

Volume of Wastewater mgd	Effluent Concentration mg/l - P 1975	Effluent Concentration mg/l - P 1980
Discharges to:		
(a) Free Flowing Tributaries of Lake Erie		
10+	1.0	0.5
1-9.9	1.0	1.0
1.0	8.0	1.0
(b) Free Flowing Tributaries of the Ohio River		
50+	1.0	0.5
10-49.9	2.0	1.0
1.0-10	8.0	2.0
(c) Lakes, Reservoirs, Significant Impoundments and Pools		
1.0+	2.0	0.5
1.0	8.0	1.0

Temperature (Goal I - State of Ohio)

(A) Warm Water Fisheries
Reduction of heat content so that in no case the discharge increase the river temperature by more than 5°F., if below the following formula applies:

Allowable Heat Discharge Rate (BTU/Sec. = 62.4 (River Flow,CFS) $(T_A - T_R)$(90%)

T_A = Allowable Maximum River Temp.

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
T_A	50	50	60	70	80	90	90	90	90	78	70	57

T_R = River Temp. (daily ave.) above discharge

APPENDIX C: DISCHARGE REQUIREMENTS TO SURFACE WATERS (CONT'D.)

Item	Goal I - State of Ohio	Goal II - Federal Government
ssolved Solids	Control to such a point that the discharged dissolved solids load does not increase the dissolved solids concentration in the receiving waters by more than 5% on a calculated basis provided that (a) the dissolved solids criterion in the receiving waters is not exceeded, or (b) the dissolved solids concentration in the discharge does not exceed five times the dissolved solids criteria for the receiving water.	$<$500 mg/1 w/specific limits established for specific inorganics, i.e., CO_2 $<$25 mg/1 SO_4 $<$10 mg/1 Ca $<$30 mg/1 Cl $<$250 mg/1 Na $<$10 mg/1 mg $<$125 mg/1 Fl $<$1.7 mg/1 @ 10°C. to 0.8 mg/1 @ 30°C. Al $<$1 mg/1 HCO_3 $<\pm$ 50 mg/1 variation over ambient conditions Mn $<$0.5 mg/1
ssolved Oxygen	4.0 mg/1 + for streams classified as warm water fisheries 6.0 mg/1 + for streams classified as cold water fisheries	No comment except BOD_5 level $\leq$ effluent DO
oxygenating Wastes (BOD_5 and SS)	Reduction so that DO level of receiving stream is not depressed below established criteria and in accordance with the following criteria.	BOD_5 $<$ 5 mg/1 SS $<$ 5 mg/1

Class I - Cold Water Fisheries

Effluent conc. (monthly) can be if ave. BOD_5 conc. increase at critical

BOD_5-mg/1 Mon.Ave.	BOD_5-mg/1 Max.Day	SS-mg/1 Mon.Ave.	SS-mg/1 Max.Day	Flow in Stream is No More Than mg/1
15	23	18	25	0.3
10	15	12	18	0.4
7	10	10	15	0.5
5	8	8	12	0.6

Class II - Scenic Waters, Streams, Reservoirs, Lakes

BOD_5-mg/1 Mon.Ave.	BOD_5-mg/1 Max.Day	SS-mg/1 Mon.Ave.	SS-mg/1 Max.Day	Flow in Stream is No More Than mg/1
15	23	15	25	0.3
10	15	12	18	0.4
7	10	10	15	0.5
5	8	8	12	0.6

Class III - Free Flowing Warm Water Fisheries

(Free flowing for at least 15 miles below discharge)

BOD_5-mg/1 Mon.Ave.	BOD_5-mg/1 Max.Day	SS-mg/1 Mon.Ave.	SS-mg/1 Max.Day	Flow in Stream is No More Than mg/1
30	45	30	45	0.5
25	40	25	40	1.0
20	30	20	30	2
15	25	15	25	3
10	15	12	18	4
7	10	10	15	4.5
5	8	8	12	5.0

APPENDIX C: DISCHARGE REQUIREMENTS TO SURFACE WATERS (CONT'D.)

Item	Goal I - State of Ohio	Goal II - Federal Government
Deoxygenating Wastes (BOD_5 and SS) Cont'd.	See below	

Class IV - Pooling Streams, Impoundments, Back Waters and Lakes Classified For Warm Water Fisheries

BOD5-mg/l Mon.Ave.	BOD5-mg/l Max.Day	SS-mg/l Mon.Ave.	SS-mg/l Max.Day	Flow in Stream is No More Than mg/l
20	30	20	30	0.5
15	25	15	20	1
10	15	12	18	2
7	10	10	15	3
5	8	8	12	5

Exceptions for Class III and IV Waters

A) In congested, heavily populated and industrial corridors where discharges of a number of identities contribute to single or multiple water quality violations - additional reductions will be required as follows:

1) Additive effects of multiple discharges shall not exceed requirements of one discharge of the combined wastes at one point, or
2) Effluent requirements will be determined by river studies w/appropriate allotment of waste loads provided no discharge exceed requirements for Class III and IV streams.

B) If slope 10'/mile or low flow depth 1.0' and free of pooling - allowable incremental increase in BOD_5 is 50%.

C) For isolated communities of 1500 or less and an untreated waste load of 2000 PE that discharges to a dry weather ditch and for which lagoons are the only practical method of treatment, allowable effluent quality will be:
BOD_5 = 30 mg/1, SS = 45 mg/1

Ammonia Nitrogen

Goal I - State of Ohio:

Stream Classification	April-Oct.	Nov.-Mar.	Calculated Stream Conc. Increase, mg/l
I and II	2.0	4.0	0.10
III and IV	10.0	15.0	0.05
	5.0	10.0	0.10
	2.5	5.0	0.15

Goal II - Federal Government: < 1.0 mg/l

Item	Goal I - State of Ohio	Goal II - Federal Government
Organic Nitrogen	No Comment	Total Nitrogen < 5 mg/l
Nitrates and Nitrites	No Comment	< 4 mg/l

APPENDIX C: DISCHARGE REQUIREMENTS TO SURFACE WATERS (CONT'D.)

Item	Goal I - State of Ohio	Goal II - Federal Government
Aluminum	No Comment	1.0 mg/l
Antimony	No Comment	Absent
Beryllium	No Comment	"
Boron	No Comment	"
Cobalt	No Comment	"
Molybdenum	No Comment	"
Selenium	No Comment	"
Thallium	No Comment	"
Tin	No Comment	"
Titanium	No Comment	"
Cyanide (total)	0.2 mg/l	Absent
(free)	0.025 mg/l	"
Phenols	0.3 mg/l	"
Aldrin	0.017 mg/l	
Chlordane	0.003 mg/l	
DDT	0.042 mg/l	
Dieldrin	0.017 mg/l	
Endrin	0.001 mg/l	
Heptachlor	0.018 mg/l	Pesticides and chlorinated hydrocarbons - Absent
Heptachlor Epoxide	0.018 mg/l	
Lindane	0.056 mg/l	
Metoxychlor	0.035 mg/l	
Organic PO_4 + Carbonates	0.1 mg/l	
Toxaphene	0.005 mg/l	
Radioactive Materials	Reduction to such a degree that (1) concentrations or unidentified radionuclides in the discharge do not exceed (a) 30 pcl or (b) limiting values specified by the AEC for water in which certain radionuclides are known to be absent; or (2) concentrations of identified radionuclides do not exceed limits specified by AEC.	Alpha Radiation < 1 pcl Beta Radiation < 100 pcl Gamma Radiation - Trace
Fecal Coliform Bacteria	May through October 200/100 ml - monthly goemetric mean 400/100 ml - 90% less than for any month November through April 1000/100 ml - monthly geometric mean (Based on 10+ samples/month)	< 200/100 ml
Virus	No Comment	Inactivated, but present at trace levels
Fecal Streptococci	No Comment	Inactivated, but present at trace levels
pH and Alkalinity	5 - 9, pH values up to 10 provided the OH- concentration does not exceed 10 mg/l if the discharge does not violate water quality standards.	No specific comment, alkalinity must be 100-130 mg/l when pH is 6-7